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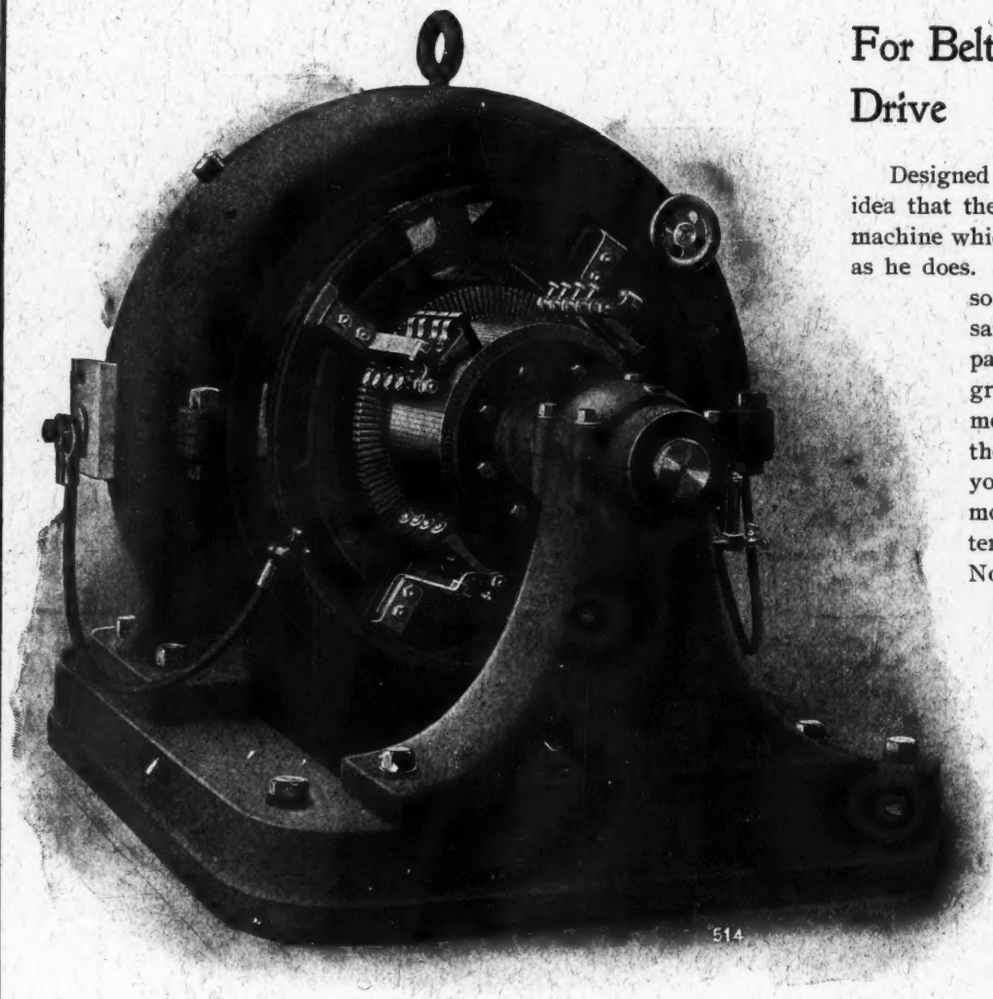

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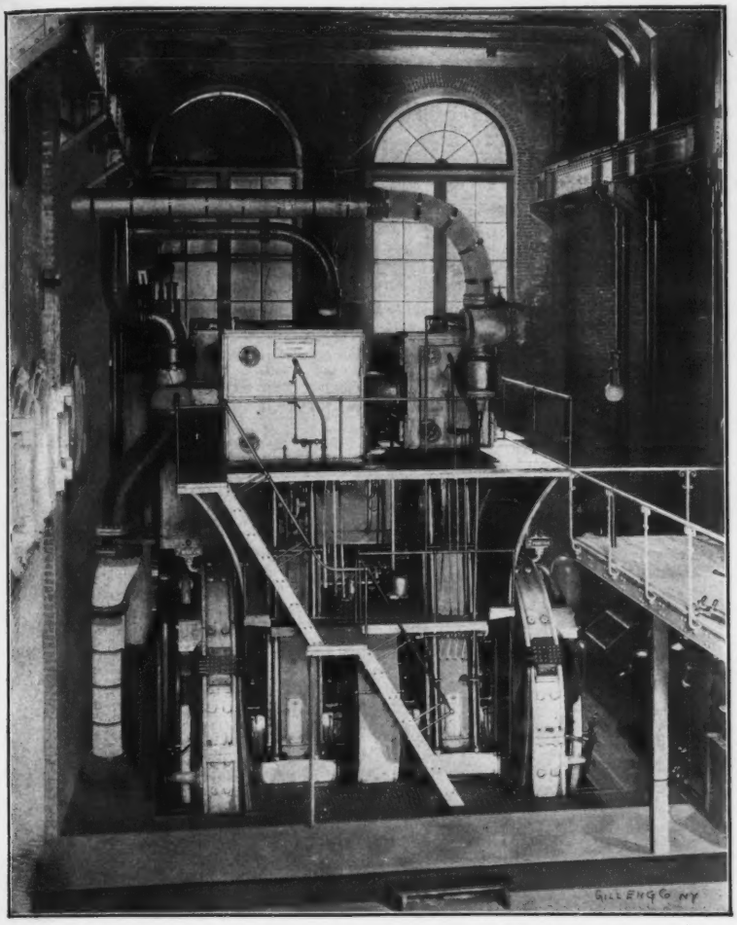

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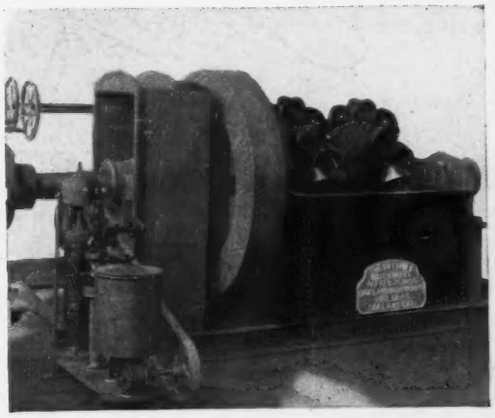

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ADVERTISERS' INDEX.

	PAGE
Akron Smoking Pipe Co.	x
Allen, Wyatt H.	v
American Circular Loom Co.	x
American Electric and Automobile Patents Monthly	vi
American Telephone Journal	iv
Benjamin, Edward H	v
Bossert Electric Construction Co., The	x
Byron Jackson Machine Works	vii
California Automatic Telephone Company	ix
California Electrical Works	vii
California Incandescent Lamp Co.	xiv
California Water and Forest Association	xvi
Carter, & Co., George E.	iii
Century Electric Co	v
Cobb, Edward S	v
Cole, John R.	x
Cory, C. L.	v
Crouse-Hinds Electric Co.	xvii
Cutter Co., The	x
Dearborn Drug and Chemical Works	iv
Doble, Robert McF.	v
Dow, Geo. E., Pumping Engine Company	xi
Electric Storage Battery Co.	iii
Fry, Donald H.	v
General Electric Company	1
Half Tone Co., The	vi
Hall, Leon M.	v
Hardwood Planing Mill Co.	i
Heald's School of Engineering	vi
Hunt, A. M.	v
International Correspondence Schools	xv
Joseph Dixon Crucible Co.	i
Knight & Co.	vi
Knowles, C. S.	iv
Locke, Fred M.	vii
Lombard Governor Co.	xii
Martin & Co., Jno	vii, viii, xii, xviii
Masson, R. S.	v
Mead Cycle Co.	xvi
Medina, Frank P	v
Meredith, Wynn	v
Moore & Co., Chas. C.	iii
National Conduit and Cable Co.	x
National Tube Company	iv
New York Insulated Wire Co., The	x
Northern Electrical Mfg. Co.	ii
Oakland Iron Works	iii
Okonite Company, Ltd., The	1
Pacific Electrical Works	xiii
Paraffine Paint Company, The	vii
Partridge, John	vi
Pass & Seymour	xvii
Pelton Water Wheel Company	xiii
Pittsburgh Reduction Company	viii
Ridley, A. E. Brooke	xiii
Risdon Iron Works	xii
Roebling's Sons Co, John A.	iv
Santa Fe Railway Company	xv.
Sloane Company, The Chas. F.	xvii
Smith, F. E.	v
Smith, W. Stuart	v
Southern Pacific Railroad Company	xv
Stanley Electric Manufacturing Co	xviii
Stanley Instrument Co.	vi
Turner, C. L.	v
Union Lumber Company	iii
Van der Naillen School of Electricity	vi
Van Emon Engineering Company	xiii
Wagner-Bullock Electric Co.	v
Wakefield, G. F	iii
Westinghouse Electric & Manufacturing Co.	viii
Weston Electrical Instrument Co	i
Worthington, Henry R.	xi

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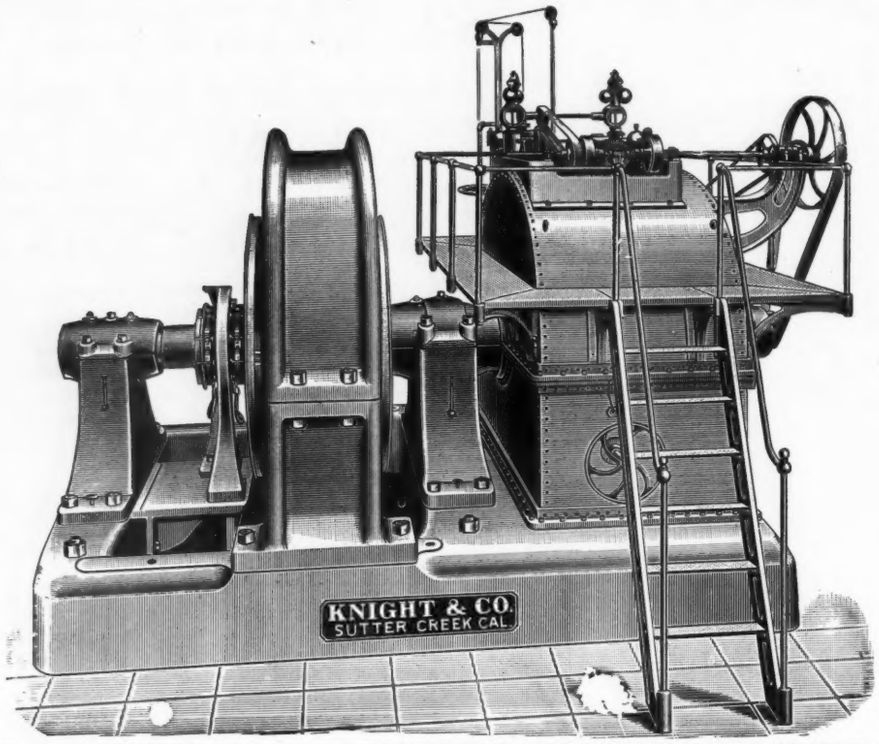

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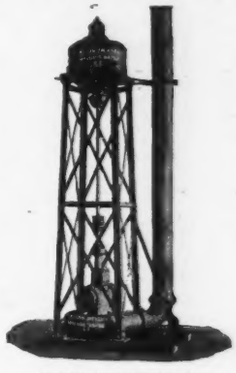

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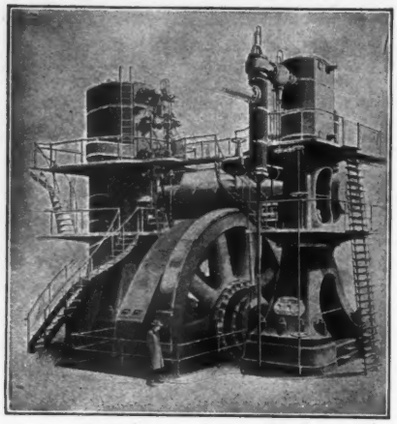

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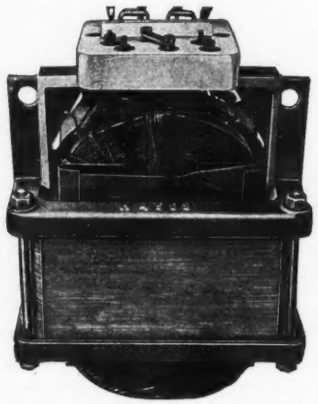

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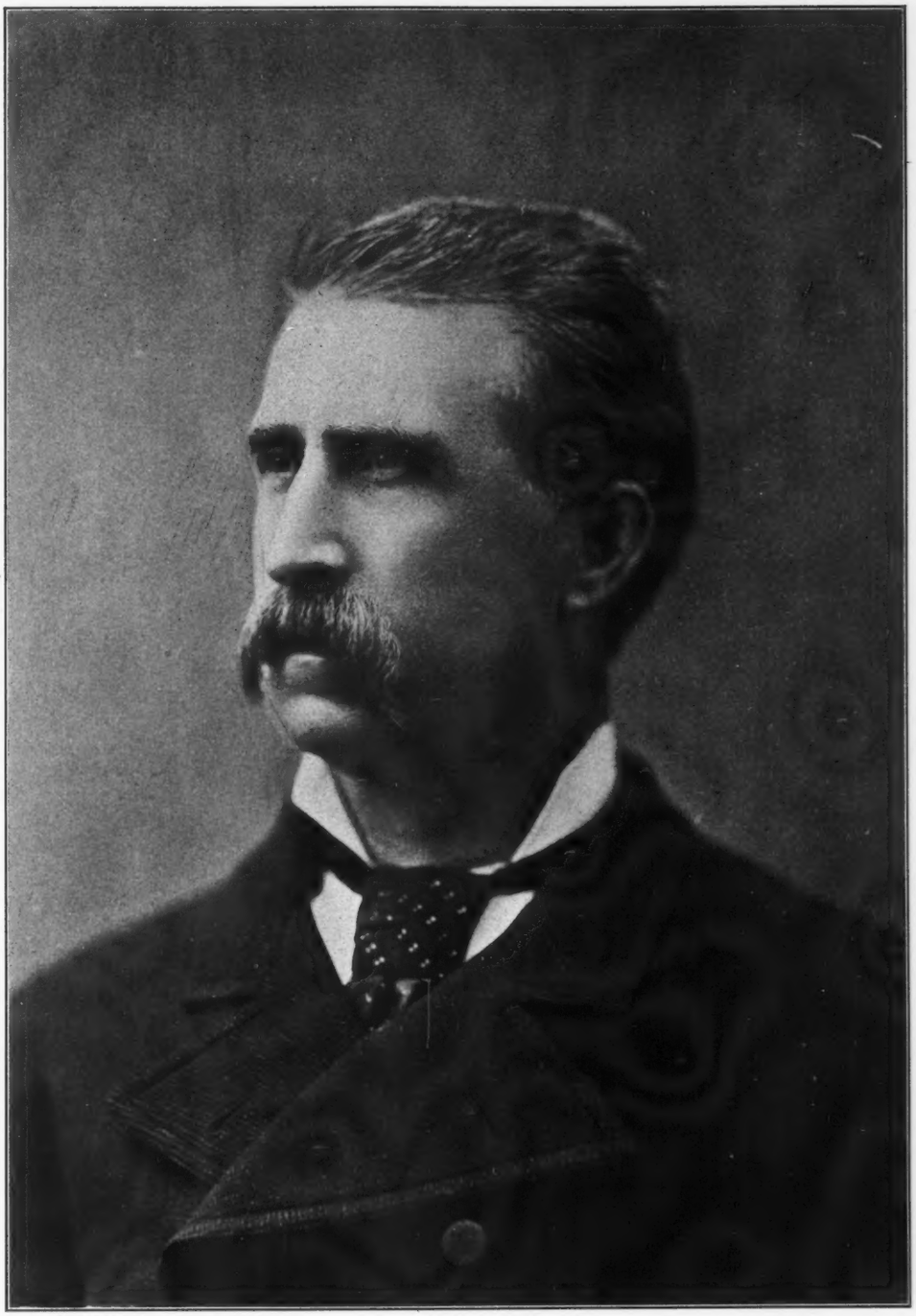

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THE JOURNAL OF ELECTRICITY, POWER AND GAS.

Devoted to the Conversion, Transmission and Distribution of Energy.

VOLUME XII. SAN FRANCISCO, SEPTEMBER, 1902. NUMBER 9

POWER HOUSE, STATION A AND R. M. JONES' RESIDENCE ON THE LEFT.

The Pikes Peak Power Transmission.

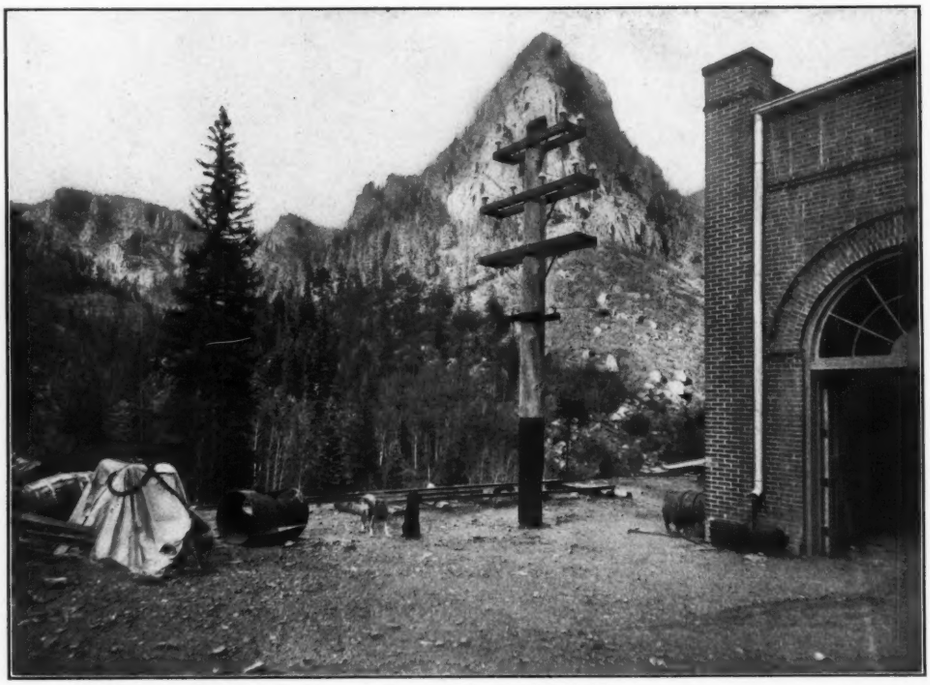
BY R. M. JONES.

THE Pikes Peak Power Company, the general offices of which are located at Victor, Colorado, was organized in 1899 under the laws of Colorado. During that year it purchased ranch property, placer claims and reservoir sites on West and East Beaver Creeks, in Teller and Fremont Counties, also located, developed and patented placer claims along these streams and at this date owns by patent all of the lands on and along these streams, including reservoir sites and all water power privileges over a distance of one and one-half miles on Beaver Creek, seven miles on West Beaver Creek and three and one-half miles on East Beaver Creek, which streams are noted for their excessive difference in altitude in short distances, which enables them to be the means of developing valuable water power properties.

The first of the several power stations which the company contemplates erecting is completed and has been in operation during the past year. This is known as Station A, and is located on West Beaver Creek, in Fremont County two and one-half miles up the stream from the junction of East and West Beaver Creeks. Incidentally, the completion of this station has accomplished much

toward the development and actual construction of stations B and C, in the way of reservoir capacity and pipe line delivery of water that is serviceable to the two lower stations after having been used through Station A.

The dam and reservoir for this system is situated five and one-half miles east of Victor, and the former is noteworthy as being the largest steel faced, granite back filled dam ever constructed. The structure is 405 feet in length along the cap, 220 feet long at the base, has a cross-section of base of 148 feet and a cross-section of twenty feet of cap. The upper slope, being the steel face, is thirty degrees from the vertical and the lower slope is fifty degrees. The vertical height of the dam from bed-rock to top of the sixteenth plate, being the spillway, is seventy feet. The spillway is forty feet wide, is cut in granite formation and passes around the northwest end of the dam. The granite back fill to which the steel plate is laid, is carefully laid in a dry wall of heavy granite boulders, which measure from twenty to eighty cubic feet each as broken from heavy blasting, with loose fine granite filling the intervening space.



MASON'S PEAK AND POWER HOUSE.

The steel plate is built up of sheets five by fifteen feet in size and laid eight plates in height with one-half inch thickness for the bottom. Continuing, the plate is reduced in thickness to three-eighths of an inch, and finally, at the cap, it is one-quarter of an inch in thickness. The entire sheet is riveted up with horizontal butt straps, and four by five by one-half inch angle bars placed vertically the entire heigth of the dam across each interval of fifteen feet for the entire length of the dam.

The five-inch leg of each pair of angle bars projects into the reservoir and constitutes a standing joint seam with an iron liner, three-eights by two inches, that is riveted between the extreme outer points of these angle bars, thus making a thorough expansion joint for each section of fifteen feet. The bottom and end connection of the entire sheet is concentrated into a deep channel way quarried out of bed-rock, and the bottom terminates in two pairs of five by eight-inch angle bars, which are riveted through the plates. The end connections are prepared in exactly the same manner, but are applied vertically. The quarrying of the bed-rock channels was carried out horizontally in each case to a point rising to an elevation, and thence the rise was made abruptly in terrace form. The entire sheet is riveted up and calked in the same thorough manner as in boiler practice. A space of six inches was left between the steel plates and smooth surface of the granite back fill. This narrow space is taken up by sand, gravel and sedimentary deposit, the filling being applied with ample water and permitted to dry before water pressure was allowed to enter the reservoir. The reservoir has a surface area of 130 acres and holds 102,000,000 cubic feet of water. The water is taken into a wood stave pipe through a perforated grizzley 240 feet long, which gives thirty times greater area than the pipe. The stave pipe is 23,200 feet long, is thirty inches in inside diameter and is of one and one-half inch redwood stave banded with one-half inch steel bands and cast iron lugs. The bands are spaced at intervals along the pipe at all distances between two and one-quarter inch and eight inch centers as necessary for resisting the internal pressure, the variations in pressure being caused by various inverted siphons along the line, two of which reach a pressure of 215 feet. This pipe line extends over very rough country, about half of the grade being through original granite formation. Many of its curves were on less than 100 feet radius, and one compound curve was on a radius of thirty-five feet. The wood pipe passes through the Skaguay Tunnel, which has a length of 1535 feet and is located 21,000 feet from the dam. From a point 200 feet below the Skaguay Tunnel, where the static pressure reaches 220 feet, the line consists of steel pipe twenty-nine inches in diameter in various thicknesses of plates, ranging from one-quarter of an inch to three-quarters of an inch, as required to meet the internal pressure with an ample factor of safety.

The total length of steel pipe, including the receiver, is 2900 feet, and it is laid on an incline averaging thirty-eight per cent. It passes over grades which have been cut through a tougher granite formation in respect to roughness than was ever encountered in railroad construction in Colorado. At one point it passes through an inclined tunnel 335 feet in length, just above which is a bridge seventy feet in height, both being on a forty per cent. gradient, while at various other points there are extremely deep open cuts. From the south end of the Skaguay Tunnel the pipe line is entrenched in the grade on which is constructed a three-foot gage railway leading from the Skaguay Tunnel to the power house, its grade being 1165 feet in the vertical in 3100 feet on the horizontal. The cars of this road, which are the only means of access to the power house, are operated by a double hoisting engine. The upper terminus of the railroad lies under a vertical ledge seventy feet in height, and all machinery, apparatus and materials of all kinds were lowered by boom and derrick, taking loads from the wagon at the upper landing and lowering them seventy feet over the ledge to the cars, from which point the loads were lowered by friction brake on a hoist equipped with a three-quarter inch steel cable. One thousand four hundred tons of building materials passed down this peculiar railroad.

The power house, known as Station A, has dimensions of thirty-eight by ninety-eight feet, with two side wings measuring sixteen by forty-eight feet each, and is located on the summit of a granite projection surfaced off true to grade. The building is constructed of brick, with arched roof constructed of steel and corrugated steel that is covered with concrete, tar and gravel. Its floor is of concrete and the building is absolutely fireproof. The building is furthermore provided with a ten-ton travelling crane.

The hydraulic apparatus was manufactured by the Pelton Water Wheel Company, of San Francisco. Each unit consists of two steel disk wheels sixty-six inches in diameter, keyed to the same shaft and working in the same wheel house. The base frames are built up in a box pattern of the same type and general design as that of the generators to which they are connected. The frames of the water wheels and generators are faced for accurate, rigid connection to each other by bolts and dowels. The connection of water wheel and generator shafts is effected by a 7000 pound steel cast balance wheel banded with a rolled tire steel band that is four inches in thickness. The wheel is seven feet in diameter, and its hub forms the connection on the water wheel shaft, and one-half of the hub forms the other half of face coupling and is keyed to the armature shaft, forming an accurate and rigid connection of the shafts of the two machines.

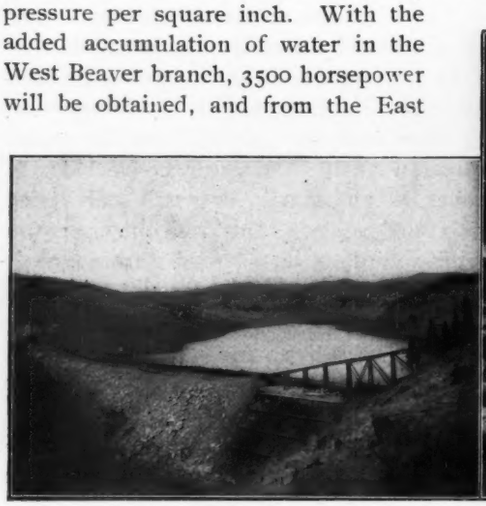
The nozzles used with which to produce the required power, as applied under the effective head of 1160 feet which is obtained, require only a diameter of one inch to produce energy of 236 horsepower, including losses. The nozzles for each unit vary in diameter, one nozzle having the capacity of the generator and the corresponding nozzles for the other wheel in the same unit being somewhat reduced. Each wheel in each unit will produce power for the full capacity of the generator connected. In operation, however, it is customary to install such varied diameter or capacity of nozzles as to permit the operation of the full capacity of the load demanded from time to time by the operation of nozzles under full pressure, entailing but slight loss in water due to regulation for low loads.

The nozzles are of the deflecting type, and work under full pressure at all times, which is the cause of such variation in the diameters of the nozzles. The regulation is of the manual or Armstrong type, owing to the fact that without reference to the class applied automatic regulation under existing conditions could only be a failure. Due provision has been taken to extend the actual control and regulation of each unit to a point directly in front of the switchboard panel belonging to that unit. The receiver runs longitudinally through the

THIRTY-INCH WOOD STAVE PIPE, 23,000 FEET LONG.

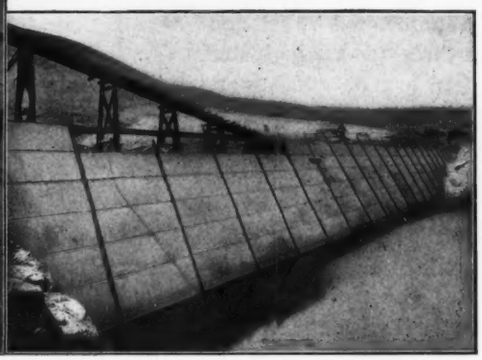
WOOD STAVE PIPE, SHOWING NORTH END OF SKAGUAY TUNNEL.

building under the steel-concrete floor. The discharge, or tail-race, water returns directly under the receiver to the south or lower end of the building, at which point it will later unite with water conducted from a point 800 feet above Station A, where a catcher dam is to be constructed, and the water diverted from the Beaver Creek channel. There being a considerable accumulation of water between the dam and Station A, it is the purpose of the company to unite the waters from Station A with this accumulation in the stream and conduct the combined waters through a pipe line to a point 200 feet above the forks of the East and West Beaver Creek, at which point there will be constructed Station B. There will be built a small pipe line up the East Beaver to the same static level as the tail-race water of Station A. The waters of both pipe lines will be united before entering the receiver. The pressure of Station B will be 1257 feet or 544 pounds pressure per square inch. With the added accumulation of water in the West Beaver branch, 3500 horsepower will be obtained, and from the East Beaver branch about 2000 horsepower, all of which may be developed at Station B.



DAM DURING CONSTRUCTION.

STEEL FACE OF DAM SHOWING CONCRETE CONNECTION WITH BED-ROCK.



STEEL FACE OF DAM DURING CONSTRUCTION.

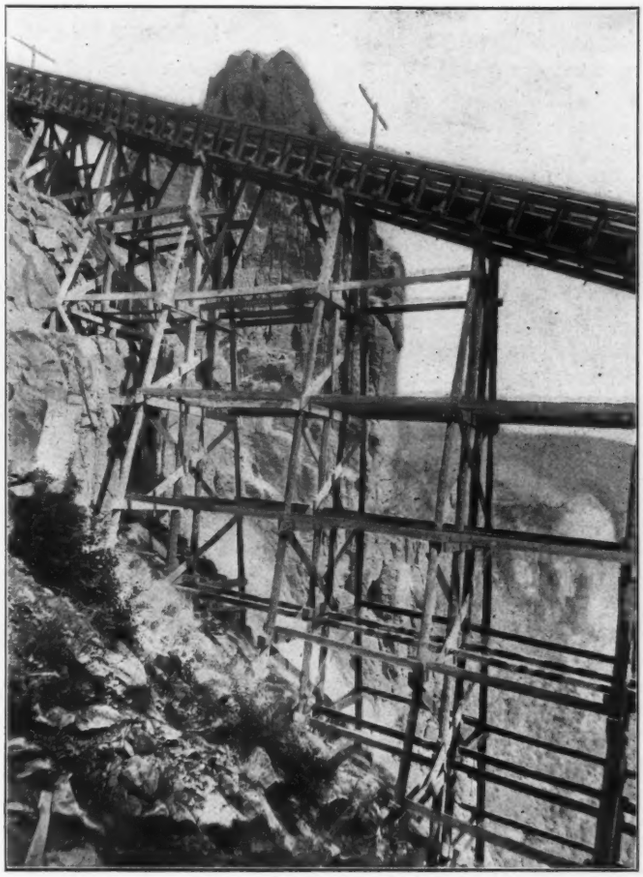
The electrical generators now in operation at Station A are four 400 kilowatt General Electric machines, three-phase, thirty cycles, 600 volts, with stationary armatures and rotary fields, making 450 revolutions per minute. As already mentioned, the generators are driven by direct connection to the water wheels. Two four-pole direct current machines, exciters having a capacity of thirty kilowatts each, run at 675 revolutions per minute, and produce an exciting current at seventy volts, each gives sufficient exciting current for all four generators while working at full load.

In reference to the efficiency of the water wheels, it may be stated that they were guaranteed to develop eighty-three per cent. of power on their shafts at full load under conditions when the nozzles are in normal position. In considering the efficiency of the water wheels, the generators were assumed to have a commercial efficiency of ninety-four per cent. at full non-inductive load, therefore with every 33,000 foot-pounds of water the water wheels will produce in current one indicated horsepower, less seventeen per cent. loss in the wheels, and six per cent. loss in the generators, delivering 78-100 horsepower, or 582 watts, from the brush holder terminals of the generators. These efficiencies have been fulfilled by tests. All water connections are tested to 800 pounds pressure to the square inch. In making the efficiency tests, measurements are made through the standard weir commonly used in the United States, which measurements are verified by spouting tests in working water through nozzles of known diameters. The developed power is measured by the highest grade electrical instruments obtainable.

The switchboard apparatus is especially liberal in design, and is made up of one exciting current panel, four generator panels, two distributing panels, two high tension panels and one paralleling or synchronizing panel. Each panel is made of Vermont marble, sixty-two by thirty-six inches, with a sub-base twenty-eight by thirty-six inches, and two inches in thickness, with a complete equipment of indicating and recording instruments, switches and regulating apparatus. The main line switches from each machine are operated independently either for power or light. The circuits are arranged so that any or all of the machines may be applied on either circuit. The transformers are six 250 kilowatt air blast type of the General Electric make, having 600 volts on the primaries and 12,600 on the secondaries. The twelve complete sets of lightning arresters are also of the General Electric make. The cable connections between the generators and switchboard and from the switchboard to the transformers are all highly insulated, paper, rubber, lead and laid in conduits in the concrete floor. Since the early operation of this station, it was found necessary to install some thorough system for combined arc and incandescent lighting, which has been fully accomplished by the installation of two 200 kilowatt compensated type three-phase generators, sixty cycles, with their full equipment. These generators are of twelve poles, and operate at 600 revolutions per minute. Each generator contains its own independent direct current exciter of twelve poles, built directly on the revolving field shaft. These machines are also directly connected to Pelton type water wheels. Finally, it may be said

that as to apparatus, building general arrangements, quality of construction and general finish, this generating station cannot be surpassed in any other like station in America.

The line transmission from Station A to the center of distribution, which is in the Gold Coin Mine at Victor, includes a distance of eight miles by pole line. The power circuits consist of three wires of No. 4 B. & S. gage, and the lighting circuits of three No. 6 B. & S. gage wires, which are ample to deliver 1600 kilowatts at less than a five per cent. energy loss. These lines are transposed at intervals of each one-half mile along the line. The poles also carry for telephone purposes two No. 10 galvanized iron weatherproof wires, transposed each 120 feet. The insulators were furnished by R. Thomas & Sons Company, of East Liverpool, Ohio. They are of porcelain, five and one-half inches in diameter, and each is made up of three independent cups. In manufacture they are subjected to a 40,000 volt salt test. The line voltage is 12,600, both on the thirty and sixty cycle lines.



STEEL PIPE AND RAILWAY BRIDGE ON FORTY PER CENT. GRADIENT.

The substation which is a brick, steel and concrete structure, and is therefore fireproof, adjoins the Gold Coin ore house, in Victor. All transmission circuits enter this building where the current is transformed through nine fifty kilowatt General Electric oil transformers, having potentials of 12,000 volts in the primary and 115 and 460 volts in the secondary, the secondary being connected in the Y four-wire system, for permitting local lighting distribution and local power work. There is also a set of three fifty-kilowatt oil transformers, 12,000 to 350 volts, which operates a 120 kilowatt rotary converter, which in turn operates a locomotive in the United Mines transportation tunnel for ore hauling from first level of the Gold Coin Mine to the Economic Mill, as well as for Bull Hill tunnel haulage. The high pressure distributing lines leave the substation in various directions, after first passing through 20,000 volt oil switches, making each line independent, to the Economic Mill, where about 300 horsepower is delivered; to the Beacon Hill power distribution for hoists, power and lights; to the Deadwood Mine, where a 100 horsepower air compressor is operated. Furthermore, the secondary 460 volt power circuit reaches Independence, Altman and the Wild Horse districts. Another primary line reaches Cameron and Gillett, after first passing through Goldfield, all for lighting services, and distributed in each of these towns through local transformers connected in delta.

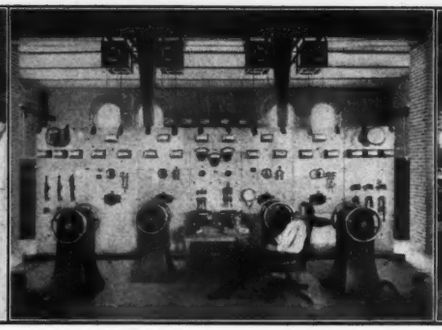
Two additional primary distributing lines reach Anaconda, where independent lighting and power is distributed to the town of Anaconda and the various mines in that vicinity, notably the Morning Glory and Doctor-Jack Pot mines. These lines also reach Elkton on its way to Anaconda, where lighting is also distributed.

The Pikes Peak Power Company has just begun, in fact, to reach its various points of distribution. It has reached all the places and properties mentioned with a good series alternating system of sixty cycles arc lighting, which is distributed in three directions through one seventy and one fifty light constant current transformer located in the Victor substation.

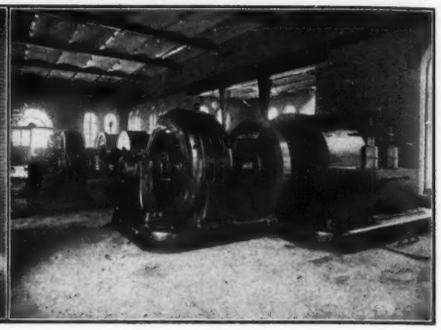
It is the purpose of this company to construct an independent transmission line from Station B to Station A, and possibly an independent line to the distributing stations in Victor, including the connections through Station A, thus permitting the entire energy of the stations to work in parallel over either station's lines or to work each station independently as desired. It is also proposed that transmission lines will be extended from these stations to other localities within reach. Thus, with two complete pipe lines, pole lines and generating station systems, the most unquestioned reliability may be counted upon. The distribution of light and power, together with the company's independent telephone system, constitutes one of the most valuable systems of its kind in the country.

It is also the intention of the company to install a third station on the combined Beaver streams at a point near the mouth of the canyon, and approximately two miles below Station B, the lower one to be known as Station C. Here the difference in elevation is but 373 feet, but the volume of water it is believed will reach fifty second-feet, which could develop 2100 horsepower, less losses. The company also owns an excellent reservoir site on East Beaver Creek at an elevation of 1700 feet above Station B and but two and one-half miles distant, which reservoir may

INTERIOR STATION A.



SWITCHBOARD, STATION A.



INTERIOR STATION A BEFORE COMPLETION.

be developed to excellent advantage in the near future.

As to financial considerations, it may be stated that the Pikes Peak Power Company has a stock issue of $1,000,000 and an authorized bond issue of $150,000, all of which is owned by the Woods Investment Company, of Victor and Colorado Springs. The present cash value of the power company alone is over $1,000,000. The power company is represented by Warren Woods, president; H. E. Woods, vice-president; F. M. Woods, secretary and general manager, and R. M. Jones, engineer and general superintendent.

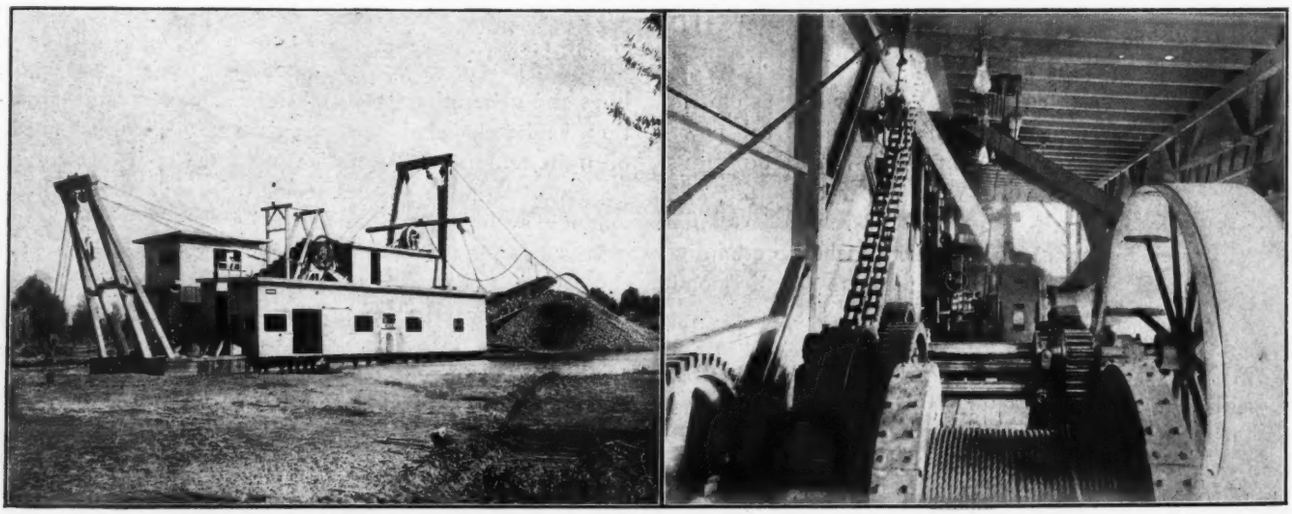
The company was organized and the property developed originally by the Woods Investment Company for the purpose of supplying power and light to the milling and mining interests owned and controlled by them in the Cripple Creek mining district, but the work of construction was carried out to much larger magnitude than at first intended, therefore the company is now supplying current to other properties and doing a large proportion of the lighting in the various towns in the district.

The engineering in every department of the construction, from the beginning to the present operation, was carried out by R. M. Jones, who will be remembered by many as the engineer of the Big Cottonwood Power Company and the Jordan Narrows plant, both in the Salt Lake Valley, Utah, and prior to this in the construction of central lighting plants and street railways in Wyoming, Montana, Utah and Nevada, beginning with the Laramie Edison plant in 1886.

A GOLD DREDGER OF THE FEATHER RIVER DISTRICT.

GOLD dredges operated by electric motors are doing much to reclaim the enormous wealth of gold lost by the wasteful methods of early mining. The chief point of activity in this direction in California at present is on the Feather River, near Oroville. In early mining days the Feather River was the scene of great activity in placer mining, many million dollars worth of gold being taken out of Feather River Canyon, above Oroville. A great deal of this gold, owing to primitive methods of handling, was not saved and was deposited with the slickens on the flats at the mouth of the canyon, below Oroville, where an area of about 10,000 acres is now being partially worked over by gold dredges. Hydraulic mining having been prohibited, and the bed-rock being found at a great depth, the only feasible method of lifting this gold bearing gravel from the bed of the river or old channels is by the dredging process of mining. The profits of operation have frequently been $1000 per dredge daily.

Each dredger costs from $40,000 to $75,000, depending on its capacity. The operation of the dredge is accomplished entirely by electric motors, the current for which is obtained from the transmission circuits of the Bay Counties Power Company operating in this neighborhood. Transformers are usually placed upon the bank to lower the voltage of long distance lines, and flexible cables run from the bank to the top of the dredge and from there to the various motors. There are usually installed motors of an aggregate capacity of 75 horsepower to 200 horsepower on each dredge. The accompanying photograph shows a variable speed Westinghouse induction motor driving a counter-shaft from which the main dredging buckets are operated. These buckets raise the material from the bed of the river to the shaking screens on the top of the dredge.

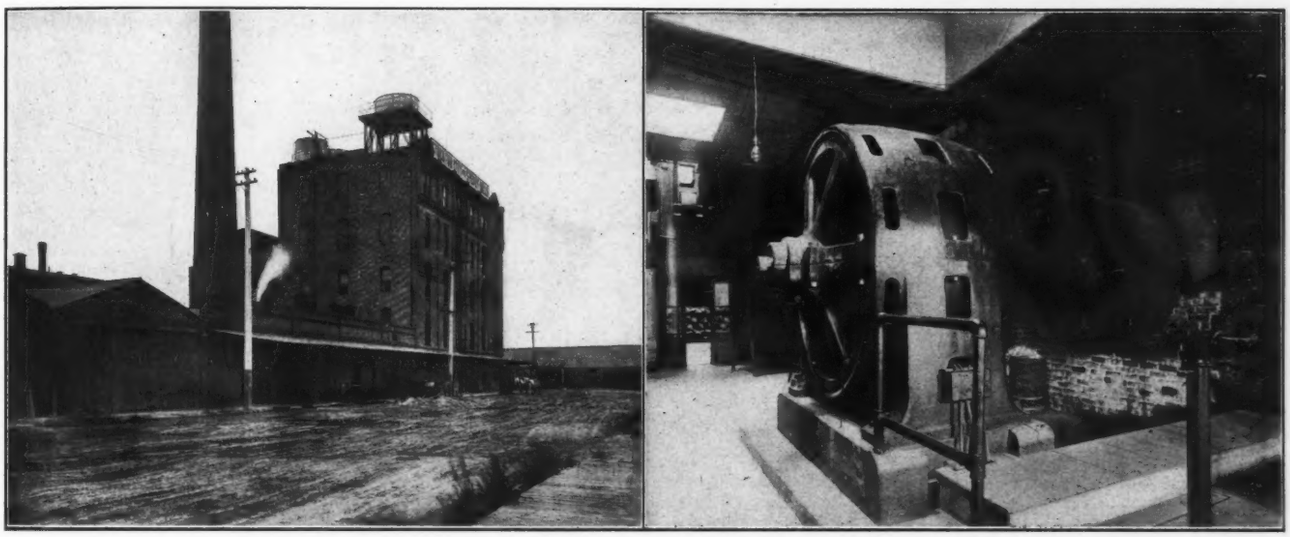


TWO VIEWS OF A BUCYRUS GOLD DREDGER ON THE FEATHER RIVER.

The Induction Motor and the Rotary Converter.

ON August 22d last Mr. Chas. F. Scott read a paper before the Eighteenth Annual Convention of the American Institute of Electrical Engineers, at Buffalo, upon "The Induction Motor and the Rotary Converter and Their Relation to the Transmission System," which was so replete with testimony concerning mooted points in the application of electric power from transmisson lines in the West that it was published in full in these columns for January last*. Not until recently have the transactions containing the discussion of this paper appeared, and as the meat of every paper is digested best when assimilated with the discussion of it, an abstract of the discussion is now given—we say *abstract* because while the discussion pertained to several papers conjointly, portions of it relating to Mr. Scott's paper are reproduced below. The engraving given of the Sperry mills, Stockton, and its induction motor were not brought before the Buffalo meeting, although the motor was alluded to anonymously.

After all, does not the question of induction versus synchronous motors resolve itself into the hackneyed one of local conditions? Experience is being gained rapidly out West here, and we have learned that both forms of motors are trustworthy, that the induction motor is the more fool-proof, that the synchronous motor and its half-brother, the rotary converter, have equally valuable attributes—that, in brief, when the former is put into service anywhere out on the system it will take care of itself in every instance, and when the latter is placed in operation in



THE SPERRY MILL, STOCKTON, CAL., AND THE 150 HORSEPOWER INDUCTION MOTOR WHICH DRIVES IT.

the substation or elsewhere it will prove unfailing under most trying conditions, witness, for instance, the behavior of the 150 horsepower synchronous motor at the Sperry Flour Mills, in Fresno, one day last summer, when the exciter circuit opened, killing the motor fields. The mill ran on as usual, and the mill hands knew nothing of the accident until advised of its occurrence an hour or so later. Nevertheless the simplicity of the induction motor will always give it the preference for general use; but the relegation of the synchronous motor to the substation for the driving of generator sets of other machinery would be a praiseworthy act, for it would enable the station attendant to keep the power factor of the system under his own control, which is a far better thing to do than to place it under the control of the consumer. Give the consumer all the induction motors he will buy, the more of them there are and the bigger they are the better, so long as the system is not handicapped in generator and line capacities, but keep the synchronous motors where they will do the most good to the system at large.

The hobgoblins and bogies and gnomes which gave affright to the childhood of electric power transmission have gone the way of its swaddling clothes, for transmission is now a very matter of fact organism. It takes events as they come, whether little or big, and the motor question is, to it, merely an event. More than this, it is an event of waning interest, for ere long it will be laid away with its forefathers, prominent among which are the questions of alternating versus direct currents, electricity versus gas, and, well, day versus night, for instance. Each has its place, and we are learning where that place is.—THE EDITOR.

Mr. W. L. R. Emmet.—There is a statement in Mr. Scott's paper which seems to imply a certain limit of the usefulness of electrical apparatus through possibilities of trouble which may occur in its use Mr. Scott's paper rather implied that it was necessary to design dynamos, motors and rotary converters to suit one another; that the synchronous motor must be adapted to the condition of its operation, and that if the voltage was not exactly adjusted it gave rise to troublesome, expensive or destructive fluctuations of current or voltage in the system. I do not think that in practice those troubles have ever

*THE JOURNAL, Volume XII, page 18, January, 1902.

existed. Neither does it appear necessary for any skilled manufacturer of such apparatus to say to a producer, "This is only adapted to use with motors of a particular design, and with certain kinds of rotary converters, and if your conditions are altered and you have to put something else on your system, troubles will arise." Take, for example, the action of the synchronous motor with variations of the electromotive force wave in a generating plant, or variations of speed in a system, or variations of voltage in a system. In the case of variation of the electromotive force wave the differences between the inherent wave of the synchronous motor and of the generator, are ordinarily differences of considerably higher frequency than the main wave of the system. They are simply overtones which are largely obliterated by the effects of self-induction, and the worst that can result are certain cross currents in the period of those overtones. These are so small relatively to the main oscillations of the system, that they are inappreciable; and in practice rotary converters and synchronous motors operate all over the world, on all sorts of electromotive force waves, and under all sorts of variations and conditions, and the troubles are apparently as infrequent where there is no conformity of wave as where there is perfect conformity. Practical experience teaches us that synchronous apparatus, operating in parallel is, in spite of these theoretical difficulties, quite rugged and serviceable where the conditions of design are proper. Another matter which has been unduly dwelt upon by Mr. Scott is the importance of adjusting synchronous motor fields to conform to change of voltage on the line. The synchronous motor with fixed excitation tends to act as a steadier of the system, its variation of power factor with change of load being very small when the motor is ordinarily proportioned. While everything that Mr. Scott says about the usefulness of the induction motor is true, there are, as he also admits, wide fields for the use of the synchronous motor. In practical service the troubles which he has mentioned are not often sources of interruption.

Dr. A. E. Kennelly.—Mr. Scott's paper gives a distinct and useful differentiation between synchronous motors and induction motors, but I think the comparison is somewhat severe to the synchronous motor. Only a few years ago we were very glad to have the synchronous motor, before the induction motor made its appearance, and now that the synchronous motor has its duties largely replaced by the induction motor, I think it is a little unfair to an old friend to underrate it. Moreover, in the mixed systems of long distance distribution I think it is desirable to employ both synchronous and induction motors, each in their proper spheres of action. Without synchronous motors the power-factor of a system may be unduly low.

I would also like to put in a plea for dropping that unfortunate word "rotary," in connection with converters. It seems to have become fixed in our minds that a converter must be a rotary converter. Of course, a converter, as we understand it, must go round; but would it not be possible on an occasion like this to take some steps for dropping an unnecessary word which plays no useful part?

President C. P. Steinmetz.—While I can fairly agree with the second part of Mr. Scott's paper, I am sorry to be obliged to disagree from a considerable part of the first portion, giving a comparison between synchronous and induction motors. Whatever I shall say, and with all deference to Mr. Scott, refers to motors of larger sizes, since we all agree that in small, and very small sizes, the induction motor is preferable by reason of its simplicity, due to the absence of the exciter, and since in small motors the objectionable features of the induction type are not so serious and can be eliminated to a large extent by the judicious use of some large synchronous motors in the same system. I have controlled the design of some hundred thousand kilowatts of induction motors, and some hundred thousand kilowatts of synchronous motors. I believe I have been fairly successful with either type, and so have no preference for one or the other design; but some years ago, when a discussion came up on this topic before the Institute, I made the statement that "I see no excuse ever to use an induction motor where a synchronous motor can be used," and my experience has not yet shown me any reason to change that opinion.

Coming now to the parallel columns, I must not only take exception to some things stated, but also add that a number of points have been omitted which appear to me essential for a fair comparison, as, for instance, that there are two essentially different forms of induction motors, the "squirrel cage" motor, which is ideal in its simplicity, but requires the same excessive starting current as the synchronous motor, and the rheostatic motor which consumes in starting the same current as when running with the same load, but requires rheostat and collector rings and brushes or switches. Obviously only a few of the statements can be discussed.

Regarding auxiliary apparatus, the "squirrel cage" induction motor, if required to start at moderate current, needs a starting motor just as well as the synchronous motor. The difference between the "some form of transformer for reducing the voltage" in the synchronous motor, and the "auto-transformer for reducing the electromotive force for starting" in the induction motor, I fail to see.

Exciter and field rheostat are indeed not required for the induction motor, but armature rheostats with switches or collector rings are required if the induction motor shall give a good starting torque with moderate starting current.

All the statements regarding adjusting the field currents, which are repeated several times, are greatly exaggerated. With any reasonably fair synchronous motor, without adjustment of the field excitation but at constant excitation at all loads, the power factor will never fall as low as it is with the induction motor at the same load.

No "squirrel cage" induction motor with reasonable efficiency starts at full load excepting with currents many times larger than full load current, so that the "squirrel cage" induction motor shold be started light, the same as the synchronous motor.

In the construction, the "field winding of many turns liable to accident" is in the synchronous motor not different from the field winding of a low voltage, continuous current machine, and the latter is considered nearly as safe as any piece of electrical machinery.

Collector rings and brushes or switches, and in addition a rheostat, are required in the induction motor if starting torque with moderate starting current is desired.

Here it should be added that the synchronous motor has the advantage of a good mechanical construction with a generous air-gap between stationary and revolving parts, while the induction motor to have a reasonable power factor must run with microscopic clearance between stator and rotor.

The synchronous motor is started by throwing a switch in starting, and then in running position, like the induction motor, and then gives the same small torque with large current. The only additional feature is that after the start the field switch of the synchronous motor is closed. The synchronous motor can, however, also be started with small current by the use of a starting motor which brings it to synchronism.

Neither the induction motor nor the synchronous motor when thrown out of step by overload will recover, excepting when the load is thrown off.

The starting of the synchronous motor is no more inefficient than that of the "squirrel cage" induction motor, and the maximum torque of the synchronous motor is frequently greater than that of the induction motor.

No alternating current motor can operate efficiently at fractional speeds except by changing the frequency or the number

of poles, etc., and the synchronous motor, as well as the induction motor, is essentially synchronous regarding speed.

Regarding current consumed in starting, I have never seen or heard of a large and efficient "squirrel cage" induction motor giving full load starting torque with one and one-half to two and one-half times full load current. Four to six times is as a rule nearer the facts.

The wave-form as a factor in explaining misbehavior of alternating current apparatus is rather discredited nowadays. While the influence of the wave-forms on the current can be observed in the induction motor, even more than in the synchronous motor, especially when running light, this feature becomes negligible at load.

The next paragraph of Mr. Scott's paper is the only consideration regarding the decision between synchronous and induction motor which I consider justified. It means that the use of the synchronous motor is restricted by certain limitations regarding steadiness of frequency, resistance of supply lines, etc. Where these limiting conditions are fulfilled, the synchronous motor does not hunt and is preferable to the "squirrel cage" induction motor. Outside of the limits of operativeness of the synchronous motor the induction motor must be used. Obviously where excessive starting torque and small starting current is needed the induction motor with variable armature resistance is appropriate.

As stated before, without adjustment of the field current, synchronous motors give power factors higher than induction motors, but by varying the field current the synchronous motor can be made to compensate for objectionable lagging currents produced by other parts of the system, as by induction motors. It is true, indeed, that the synchronous motor represents an active or live electromotive force. This frequently is one of its most valuable features, that, with the supply of electric power failing, the synchronous motor, and also to a lesser extent the converter, driven by engine power, is ready to turn generator, and so becomes the generator reserve of the sub-station, supplying power to lights, induction motors and other dead loads on the system. This feature is utilized sometimes to such an extent that during the daily changes of load the synchronous motor regularly changes from motor during daytime to generator during the peak of the lighting load.

Regarding the summary, most of the statements have already been discussed. It should be, however, added here that the synchronous motor is smaller than the induction motor, more reliable in its operation, and is of a higher efficiency. It can be wound directly for voltages of 10,000 and more, which the induction motor cannot, and step-down transformers and the complication and loss of power inherent thereto can be saved, so that considering that the synchronous motor alone already exceeds in efficiency the induction motor, when compared with induction motor and transformer, the high voltage synchronous motor is vastly superior in efficiency. In operation and adjustment it requires no more but rather less skill than the rotary converter recommended in the last part of the paper under discussion. It appears, therefore, that the synchronous motor and not the induction motor is the type especially suited for transmission and distribution of power in large units, and the induction motor finds its proper field in power distribution in small and moderate sizes and for special applications, such as frequent starting under heavy torque, and then as a special motor.

Now, from all this, the conclusion I derive is that the synchronous motor is by no means the decadent apparatus that Mr. Scott apparently states, but is not only alive, but is preferable as a type of machine; that it is the machine which should be used wherever possible; but that there are certain limitations outside of which the induction motor must be used because there is nothing better.

As to this very high power factor of the induction motor, we must consider that even if the power factor in special cases, with a special low frequency motor, exceeds 95 per cent, the average running power factor probably does not exceed 90 per cent, but if anything is lower. A 90 per cent factor means 44 per cent inductance factor or 44 per cent of lagging alternating current and a corresponding reaction on the system and on the regulation of the generator.

Dr. F. A. C. Perrine.—I wish to add something to President Steinmetz's remarks, from my own experience as an operator of induction motors. From that experience I would say that the advantages set forth in the paper are largely possible advantages, and while any one of them may be found in a particular case, the conclusions drawn do not generally apply together. As regards the point made by the president concerning starting torque with one and a half times full load current, I know of one case where a 400-horsepower induction motor was built and guaranteed to start with one and a half times full load current, the contract between the user of the current and the transmission company having been made to require it. It that case it was necessary to insert four friction clutches between the motor and the flour mill operated by it. The first friction clutch was between the line shafting and the rolls, and so on; all of which was necessary in order to start up that induction motor and keep the starting current down to one and a half times full load current. In another case, also in a flour mill, where a high efficiency induction motor was demanded, the starting current was so great that a 450-kilowatt generator would not start a 300-horsepower induction motor. The water wheel attached to the 450-kilowatt generator was slowed down by the power demanded to start up the motor, and in addition it was found necessary to use a number of men pulling on the belt. At first the superintendent said it was a good thing, because he never had had his men on time before. With the motor in service they had to come early in order to pull on the belt and start up the mill. This was finally found to be a burden, and the owner demanded that the induction motor be re-designed so that it could start up alone. The manufacturer changed the end rings on the "squirrel cage" armature, and the motor would then start the mill without any difficulty. But the mill was paying for its power by wattmeter, and the cost of the power was increased by one-half cent a barrel of flour on account of the decreased efficiency of the motor.

And now, as regards the impossibility of running transmission plants with synchronous motors, while I in general agree with Mr. Scott that it is not advisable to put synchronous motors into all hands; at the same time, as Dr. Kennelly has said, the synchronous motor is an old friend, and in California one of the earliest transmission plants is using almost entirely synchronous motors, and its load is almost entirely mining plants. Now, there is not a plant in California which is giving better service to its customers, or a more constant voltage regulation, than that particular plant. Again, I would remark that a paper very much similar to this was discussed before the Pacific Coast Electric Transmission Association, and the concensus of opinion among the operators of the transmission plants there seemed to be that for large powers it was, as a general rule, inadvisable to use induction motors, but even at the expense of sometimes putting synchronous motors in the hands of operators who did not understand their effect on the power factor of the circuit, it was as a rule a preferable thing to use a very considerable number of synchronous motors on a line, and as a general rule a good plan to use synchronous motors where large motors were supplied. Again, experience in California has proved very conclusively the point Mr. Steinmetz made of the advisability of having the synchronous motor as a portion of the steam reserve. A serious drouth occurred in California about four years ago and continued for two years. During that time a statement was made which was nearly, although not quite true, that every synchronous motor in California was running as a generator supplying current which

(*Continued on page 174.*)

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EDITORIAL.

WILL THE PUBLIC EVER LEARN?

While the lay press too often makes itself ridiculous, and the public asinine, by utterances concerning things technical, it once in a while redeems itself, perchance through accident, by publishing something that is rational, even though that something yet be upon a technical subject. Such a publication appeared recently in a metropolitan journal* regarding Edison's new storage battery, which the public has been led to believe is capable of doing miracles, even to the navigation of the air. The mere mention that "the Wizard of Menlo Park" is developing a new form of storage battery has set the pens of sensational scribes a-wagging, and these wags have brought about a situation that is no joke. Nevertheless, their humor is great, despite the fact that it is prejudicial to vested electrical interests which have to do with the manufacture of more familiar types of storage batteries. We learn, for instance (through the medium of the sensational press), that the new Edison battery can be charged at any rate within the capacity of the charging station, which makes it possible, so it is said, to charge an automobile battery in three-quarters of a jiffy, regardless of rate of discharge. In other words, we are supposed to swallow a statement to the effect that so long as the kilowatt-hours of charge exceed the kilowatt-hours of discharge, the conditions imposed by the new battery in charging will be fully satisfied regardless of the time interval of charging. "Pump in continuously for three seconds and take out continuously for three days," they say, "and what good is the lead battery now that it is up against Wizard Edison?" And so on, *ad nauseum*.

*New York Herald.

The Edison storage battery is undoubtedly a thoroughly meritorious invention, and it is one which equally undoubtedly is destined to have a great sphere of usefulness, but time alone will tell what it will accomplish. As for the battery itself, it is not exactly new, having been on exhibition last year at the Pan-American Exposition, and Kennelly has told us* much about its physical properties. At present it is in its experimental stage, and no attempt will be made to manufacture for the market until after the battery has been put to a severe test that will last for months. Life or endurance tests are the crucial ones in the determination of the real worth of a storage battery, and the Edison element will be subjected to the most severe work that is possible. This will consist in equipping five automobiles with the batteries and subjecting them each to a run of 5000 miles over country roads. The inventor announces that his battery will occupy about the same space as the familiar lead battery, that it will weigh only about 70 per cent. as much, and that it will be more durable. A specific battery made for automobile service weighs 332 pounds and has a weight efficiency of fifty-five pounds per horsepower hour. "In the past," Edison continues, "I have nickel-plated the cells, and by so doing I have made them durable under all circumstances, but it is unnecessary to nickel-plate the cells if the battery is not permitted to go dry. This fact is stated in answer to the assertion that the nickel may flake or crack and thus ruin the cell." It is further stated that Mr. Edison believes he will be able to cover 100 miles with a single charge with a voltage loss of but 15 per cent., while on the other hand specially made lead batteries have repeatedly made runs of 150 miles and even 200 miles with a single charge. Furthermore, it has been said by men unauthorized to speak for the worthy inventor, that he is planning to put an electric automobile within the reach of the man of moderate means, and his battery has been repeatedly referred to as cheaper in construction than anything of the kind ever before attempted. Exactly the opposite is declared to be the truth, for if the new battery demonstrates its durability it will still have the defect of being more expensive in its first cost than the lead batteries which it is said it will displace on the market.

As a rule inventors do not take the public into their confidence until the time is ripe for so doing, but the public should have learned by this time that so-called "revolutionizing inventions" do not revolutionize in a day, nor in a month, nor in a year. Genuine ones *do* revolutionize in time, but more often than otherwise the time taken approaches a decade, in view of which it is well to come to the realization that the lead storage battery, with its drawbacks as to weight and durability, will become more and more familiar in electrical engineering development even as the new Edison storage battery will become more familiar in it as time rolls on.

*Transactions of the American Institute of Electrical Engineers, Volume XVIII, 1901.

THE PROCEEDINGS OF ENGINEERING ASSOCIATIONS.

It is impossible for it to be otherwise than highly satisfactory to the gas interests of the Western States that the Pacific Coast Gas Association, at its recent annual meeting held in San Francisco during the middle of July, revoked the resolution adopted in July, 1895, which constituted the *American Gas Light Journal* as the official organ of the association. As the matter now stands the official organship of the *American Gas Light Journal* ceases with the publication of the proceedings of the recent tenth annual meeting, and henceforth the invaluable papers and discussions of the association will be more widely published and read than was possible under the old arrangement.

If official organships are to be granted, it would seem to be just and proper that they should be bestowed upon the worthiest of the publications of their class that are local to the interests represented. Why should a technical organization of the Pacific Coast having its place of annual meeting fixed at San Francisco jump clear across the continent to New York before finding a trade periodical worthy to represent it? The answer to this query is found in the rescinding resolution of the Pacific Coast Gas Convention, and it is gratifying to know that action has at last been taken which enables THE JOURNAL to present its readers with full reports of the conventions of the Pacific Coast Gas Association at a materially earlier date than it will be possible for any other periodical in the country to do. Geographical location alone enables this to be possible, and when to this is added the impetus of the rising esteem in which THE JOURNAL is being held by its gas brethren, it is vouchsafed that no other publication in the country will be in a position to handle the proceedings of the coming gas conventions so fully and so sasisfactorily as will THE JOURNAL.

The light of one other most worthy organization still remains under a bushel, so far as the dissemination of its transactions throughout its sphere of action is concerned, and that organization is the Technical Society of the Pacific Coast, the works of which are known to altogether too few, yet which is one of the sturdiest and most invaluable engineering associations to be found in the entire West.

Pity 'tis that its proceedings are in bondage.

NOTING IMPROVEMENTS.

The increase in the number of inquiries for copies of THE JOURNAL and the consequent gain in friends and subscribers are matters of great satisfaction to the publishers. Even the short time which has elapsed since our last number was issued has demonstrated that our readers have not passed our remarks over unheeded, but have responded most generously.

The new advertising we received for our August number was especially gratifying, embracing as it did a full page for JOHN R. and GEORGE A. COLE, Pacific Coast agents for New York Insulated Wire Company, The Cutter Company, American Circular Loom Co., The Bossert Electric Construction Co., Akron Smoking Pipe Co., and the National Conduit and Cable Co.

The two great transcontinental lines of railroad also recognized THE JOURNAL, and hereafter the Southern Pacific Company and the Santa Fe Line will grace our advertising columns with their unique displays.

The Bullock-Wagner Company, and John R. Partridge, the stationer, are also in evidence. As all of the above named have come in on contracts for from six months to one year's time, the aggregate amount of new advertising in the August number is not inconsiderable.

For next month we hope to be able to make further gains, and so on to the end of the year, when some very notable changes will be made for the broadening of the scope of our paper in editorial matters, and a still further improvement typographically. A few more pages of the advertising department can still be added, and if you have any wares to dispose of, engines to sell, or new patents to exploit, you will find that THE JOURNAL will yield results. The present low rates cannot be maintained by us much longer, and you would do well to take advantage of them now.

Speaking of low rates reminds us to again call your attention to the small cost of a year's subscription to THE JOURNAL. No investment can yield you such a large return on so small an outlay. Let us have your and your friends' subscription while the price is still one dollar.

ADVERTISERS PLEASE TAKE NOTICE that all approved copy for the October number must be in the hands of the business manager not later than September 18th to insure insertion. The October number will come from the press and be ready for delivery September 25th, and hereafter the publication will appear on the 25th of the month prior to the month for which issued.

The superb edition of the Bay Counties System recently issued from our press has received nothing but the highest praise from all of those who have had the good fortune to obtain a copy. The edition is almost exhausted, and to those whose letters have been so full of praise and encouragement we desire to extend our sincere thanks.

These rambling remarks from the business department it is hoped will be received in the same spirit in which they are written. We feel that the supporters of THE JOURNAL are entitled to our full confidence, and that their interest in the publication so heartily expressed in their subscriptions and advertising, will not be lessened by showing the necessities of the business portions of the paper, and asking the full and hearty co-operation of our patrons to meet them. The more support we get, the more interesting and profitable we can make THE JOURNAL for readers and advertisers.

THE INDUCTION MOTOR AND THE ROTARY CONVERTER.

(*Continued from page 171.*)

would have required duplicate machinery had those plants been operated with induction motors.

Another point I wish to call attention to is the observation that for transmission work in general, as I understood Mr. Scott to say, for the operation of rotary converters as well as induction motors, it is necessary to design the generators far below the point of saturation in the field. I think that designers and operators will agree that, thought it may be that 60-cycle rotaries are successful in some cases, nevertheless, the 25-cycle rotary is a more successful machine; and so far as I am aware, all designers of 25-cycle generators are running their induction up in the fields about as high as the iron will allow; and in spite of that fact the 25-cycle induction motor and the 25-cycle rotary work as well, if not better than at 60-cycles, where the induction in generator fields is kept down, necessarily, lower on account of the closeness of the field magnets.

Mr. L. B. Stillwell.—I confess, Mr. President, that from my experience I am a friend of the induction motor wherever it can be used. I think we are indebted to Mr. Scott for his very compact comparison of the advantages and disadvantages of the two classes of motors. I do not think it is an answer to that comparison to allege that the differences shown are theoretical. I believe Mr. Scott is fully competent to discuss it from that standpoint, and I wish simply to mention one or two points which I have met in experience in operation, which have led me to prefer the induction motor in practically all cases in which it can be used. The rotary converter is necessarily synchronous with the generator. That is a fact which I have sometimes regarded as unfortunate, but at any rate we cannot get around it unless we are willing to go to the expense of buying a motor to drive a direct current generator for railway work. But the practical advantages that have been claimed for the synchronous motor, I think, reduce themselves to this one claim, that the power factor of your system as a whole is improved by its use. As to relative efficiencies there is some advantage in the synchronous motor possibly, but nothing very material. As regards the power factor advantage, it is apparent rather than real in operation. In a large system, such as exists in Buffalo today, we cannot have thoroughly skilled men in control of the stations adjusting the fields of the rotary converters and the synchronous motors with a view to affecting properly the power factor of the system. If we could put a synchronous motor in a terminal house, to which all of the overhead lines were connected, and there provide skilled attendants, it might have some value; but where you have a dozen substations, as is the case in the Niagara plant, you must put these synchronous motors and converters in the hands of not less than twenty-four operatives, since you must have at least two shifts for each substation. Now, the Buffalo companies pay men of that class about $50.00 a month, and it is not an easy matter, as I know by experience, to find men who will work for that wage and who are to be trusted with the manipulation of machinery requiring synchronism. Mr. Scott has pointed out the fact that there are a great many mistakes made in synchronizing the motor with the system and it ought to be remembered that those mistakes are made, not by members of this Institute, but by $50.00 a month men.

As to the starting current of these motors, I am sorry that I cannot find myself in agreement, from experience, with our president in his discussion of Mr. Scott's paper. I recall one instance in which a rotary converter rated at 375 kilowatts connected with a large system, required so much current in starting that the men thought that the pointers at the ammeters were going to move clear off the instrument and never come back. It took apparently five times the kilo volt-amperes that it should have taken, and today the most satisfactory rotary converters, to my mind, that are operated from these large power plants are those which use induction motors to start with. I cannot say how it is today, but when I saw it not very long ago, one of the stations at which the rotary converters had been made self starting had been forced to abandon that method of operating and to start from the direct current side, by direct current obtained from another rotary converter, which was started by an induction motor.

There is one other point that I would emphasize as objectionable in the synchronous machinery, and that is this: in an independent system it is inevitable that there will be short circuits. The cables in some parts will break down at times. If the circuit breakers in the substations and in the power house can be suitably arranged it is possible, at least theoretically, to localize that trouble if the motors used are such that they will not instantly fall out of step when the momentary drop of potential occurs. Now, it is true that these synchronous motors and rotary converters are supposed to drop out of step only when the potential drops to about 50 per cent of the normal value. That may or may not be so, but there are occasions when the potential does drop to 50 per cent of the normal value, and these machines let go and stop when I am satisfied that an induction motor would not let go. The lighting system of the city of Buffalo today is operated by synchronous motors. To my mind it would be better to operate it by induction motors, for the reason that at times, not so infrequent as we might wish, there will be momentary drops of potential, caused by short circuits. These may last only half a second, but half a second is a long time when measured by alternations of current, and it is long enough to make these machines let go, and then the service is interrupted. This may be answered by saying that the regulation of the machines at Niagara Falls is not first class as judged by modern standards, and that is true; but the improvement that can be effected by bringing up the regulation of the generators is a quantitative one, and I am not at all sure that with the best that can be done in improving the regulation of the alternators we shall escape the difficulty that now exists, in view of the fact that we have line drop and drop in the transformers, as well as drop in the alternators themselves.

As to wave shapes, it is true that the power company has not had any trouble very recently with the operation of synchronous motors or rotary converters from that cause; nevertheless, it seems to me that it is wise in designing machinery to attain as nearly as possible a perfect sine curve. I regard it as a misfortune that the potential curve of the Niagara Falls alternators is flattened, and we have sometimes suspected that a third harmonic was responsible for some of our cable troubles.

It seems to me that the argument that you need pay no attention to wave shapes because inductance tends to reduce them to a sine form, is on a par with the argument of a man who should say, "It is no use to cut gears with great care, because they will wear themselves all right if you give them time."

As to the clearance of the induction motor, it is true that it is necessarily less than the clearance of a synchronous motor of corresponding output, and for this reason, mechanically, the motor is not quite on a par with the synchronous motor, but I have never known a case where in America the small clearance has led to trouble. If one-twenty-fifth of an inch has been used abroad in some of these transmission systems, I can well imagine it would be very difficult to keep the machines lined up; but with ordinary care I believe a good clearance in the induction motor will admit of a power factor at full load of 90 per cent and upward, which is sufficient.

Mr. Oberlin Smith.—Mr. Scott's paper interested me very much in its presentation of the deadly parallel columns. The left hand one seemed to involve almost as much as the rules of golf, and to involve also the consulting engineer, which in that game we call the caddie. This may probably be one of the objections to the synchronous motor, where it is used in num-

bers about an establishment, rather than its small size. I am not competent to judge of it in station work, not being experienced in that line. Very likely these motors have much value where conditions are uniform and the plants are large. I speak, however, rather from the standpoint of the user and adapter of motors than from that of the maker and designer,—from the standpoint of the mechanical engineer. Now, there is one very important field that small motors can occupy; that is, running individual machine tools, including presses, for punching, shearing, drawing and such work. I believe the time is coming when all our new machine shops will do away entirely with shafting and belting and use individual motors. An important question that is to be solved in the immediate future, is whether these motors will be continuous current machines, such as are now mostly used, or whether alternating current can enter the field. Very probably it can, but in such cases it seems to me that the induction motor must be more suitable than the synchronous, because of its simplicity. As a mechanical engineer, I think the induction motor will appeal to all of us of that profession as much the simpler machine, where you simply have a rotary shaft running through bearings, and where it will run of itself, as has been expressed by Mr. Scott—go on of its own account and be happy. Whether synchronous motors always will thus remain joyful may be open to doubt.

Mr. Ralph D. Mershon.—As regards the question of the power factor of motors, I do not want to go into a discussion on the relative merits of synchronous and induction motors, but I will say this, that I lean toward the induction motor when it comes into competition with the synchronous. However, I think that each motor has its own place and its own particular sphere, and it is a question of judgment as to where one sphere begins and the other ends. But there were one or two points made with which I cannot quite agree. One of them is as to the power factor which can be maintained under working conditions with the synchronous motor. I do not think it can be maintained at anything like the figure that is ordinarily given. As to the synchronous motor, connected, as Mr. Steinmetz suggested, without any field rheostats, I do not think there is any circuit operating in this country, unless with phenomenally good attendance, where a power factor of 95 would be maintained. I think the change in voltage on the circuit, the change in resistance in the motor field and all the other changes that would occur, would cause the power factor to vary a considerable amount from this value.

As regards the relative efficiency of the two machines, I am not going to speak from the standpoint of design, but I would like to speak from the standpoint of the men who are receiving competitive bids. Some time ago I had occasion to prepare specifications for motors, motor generator sets of considerable size, and I asked for bids on both synchronous and induction motors. The machines were in the neighborhood of 500 kilowatts capacity. The efficiencies guaranteed by the different competitors were almost exactly the same. They were practically the same on induction and synchronous motors from the same makers. I may say also that on those sets the power factors guaranteed for the induction motors at full load were in one case 92, and in the other 92½ per cent. which I thought was pretty good.

President Steinmetz — Regarding the synchronous and the induction motors at low voltage: obviously, the advantage of one or the other motor depends on the shape of the torque curve, and no one has ever mentioned and I know of no publication on, the shape of the synchronous motor torque curve, as a function of the impressed voltage. Some years ago I had, however, some careful investigations made which led me to the conclusion that the maximum torque of a synchronous motor, within a certain range, varies in direct proportion to the terminal voltage, so that a drop of voltage of 10 per cent. will lower the maximum torque of the synchronous motor only 10 per cent., while we know that in the induction motor the maximum torque varies with the square of the impressed voltage. Thus, other things being equal, the synchronous motor with low voltage will maintain its torque longer than the induction motor. The reason probably is, that with the induction motor the two factors of torque, the magnetic field intensity and the induced armature currents, both decrease with the impressed voltage, while with the synchronous motor, the one factor, the field intensity, is at constant field excitation, more nearly independent of the impressed voltage. The synchronous motor is sensitive, however, to rapid changes of frequency.

Professor Wm. A. Aldrich — In regard to the paper by Mr. Scott, we have had some experience in throwing in induction motors on synchronous motor circuits, and found as mentioned, very pronounced disturbances, especially when the synchronous motor is operated on a circuit with marked phase displacement. As induction motor may be thrown in on a synchronous motor circuit practically without any regard to the load on the induction motor, when the synchronous motor is operated at or near its normal excitation; that is, essentially at unity power factor. The synchronous motor would repeatedly break down when the induction motor was thrown upon its circuit if the synchronous motor were over-excited, so producing heavy leading currents equivalent to a large capacity effect on the line. The object in view was to neutralize the capacity of the over-excited synchronous motor with the inductance of the induction motor. It was found impossible at times to effect complete neutralization. In practical operation it is usually necessary to bring the synchronous motor to normal excitation or unity power factor. The induction motor may then be thrown in, and the excitation of the synchronous motor increased above the normal with its corresponding condenser effect to offset the inductance. The machines cannot be instantly or suddenly thrown in under any load or with any excitation. That is pointed out in Mr. Scott's paper. Your attention is merely invited to this as an experimental demonstration. We have repeatedly tried to corroborate these principles in the laboratory. Perhaps there are others who have similarly used much larger commercial units.

Another point is brought to our attention in this relation; namely, the large current carrying capacity of the synchronous motor required. We used two, four and seven kilowatts induction motors on a 7½-kilowatt synchronous motor circuit. With such varied induction motor reactances it was practically possible to effect neutralization, bringing the circuit to unity power factor. Conditions arose, however, in the synchronous motor where with practically no load upon it, a 100-ampere fuse would be blown, which was much over the normal rated capacity of the machine. Unless precautions are taken under these and similar conditions of extreme phase displacement fuses will be blown under no load.

Vice-President Dunn—The floor is now extended to Mr. Scott for the closure of discussion on his paper.

Mr. Scott—I will limit myself to a few general statements which will cover quite a number of specific points which were brought up in the discussion upon my paper. Both President Steinmetz and Mr. Emmet pointed out quite truly that the various so-called theoretical difficulties in the adaptation of synchronous motors to the circuit, were fortunately those which were seldom of actual occurrence, but both of the gentlemen used substantially similar expressions to the effect that the troubles do not occur where the conditions of design are proper. Those conditions of design have fortunately been determined by the larger companies and the principal engineers operating this kind of apparatus. Those principles of design were not secured off hand or a priori, but have been somewhat of an evolution from experiences of the first few years in the application of the earlier apparatus in service. Looking at the subject in a broad way, any generator, or any motor, made by anybody, is not likely to follow these conditions of proper design. The requirements, therefore, for the successful operation

of a synchronous motor, demand of the designer, the consulting engineer and the purchaser, a closer and different class of attention than is necessary for the induction motor. I am not at all taking the position that the synchronous motor will not work, or cannot work, or does not work; but I have endeavored to point out certain conditions of difference, mainly those in service, which have led to the large introduction, and I think the ascendency, of the induction motor.

A number of times in the discussion, the starting current, that great bugbear in many minds in the consideration of the induction motor, has been brought up, but I have failed to see pointed out by any of the speakers anything to show that the synchronous motor would do better. What can be done with the synchronous motor? If a starting motor is used, or some other device, why, we have the same thing available for the induction motor, but usually the induction motor can itself do better than the auxiliary device could do. It has been noted that in some places the effect of starting the induction motor with load is to "kill" the system. What would the synchronous motor do under similar circumstances? It is pointed out by Mr. Stillwell that in a certain case, one type of synchronous motor, that is, a rotary converter, took some five times its full load current for starting without load. Even granting that the induction motor would do the same, it could do more than start its own armature, for it would in that case be developing more than its full load torque.

The matter of efficiency in power has been referred to and attention is called to possible differences of a few per cent. There is something larger to consider than this, and that is the efficiency in service. If one class of apparatus gives assurance of less trouble in operation, less liability to accident, less shut down in the circuits and service, that demands a considerable preference over one which may have liabilities to disaster, although it may have a little greater efficiency. It has been pointed out that the synchronous motor and the induction motor behave differently on lower voltages, that a lowering of voltage of 10 per cent. will lower the maximum capacity of the synchronous motor by 10 per cent. and that of the induction motor by about twice that amount. The criterion to settle a point of this kind is that of serivce. In which case, with which class of apparatus is there the most difficulty from this cause? And, where difficulty does occur, with which is the more serious? Another point may be made, which is referred to in my paper, in the comparison of the two motors. If the synchronous motor is overloaded its speed curve takes a vertical drop. If the induction motor is overloaded it comes down in speed slowly as it has torque at low speeds, thus making use of the stored energy in the system.

Dr. Perrine has made a few specific statements regarding the operation of some motors of large size. He has given certain facts, enough, I think, for me to identify the cases to which he refers—one, I think, a 400 horsepower and the other a 300 horsepower motor. He states that in one case, the 300 horsepower motor could not receive enough current to start a flour mill when operated by a generator of a little larger size, I think, 400 kilowatts or such a matter. There are certain other facts there. One is that to start a flour mill requires a very large torque, as the parts of the flour mill get in position where it requires a very great effort to start them, so that a torque considerably greater than the normal running torque is necessary for starting a complete flour mill. Any motor would legitimately be allowed a fair current for starting. In this case I have not the figures exactly in mind. My best recollection is that the generator supplying this current was unable to give a current to the motor equal to, say, twice the full load current. The generator was one of a type with the saturated field, so that a very considerable field current is required for increasing voltage, and the exciter was doing the best it could as its belt was thrown off during the process of trying to give enough exciting current to the generator to start the motor. At reduced voltage and at a power factor of about 60 per cent. the generator could give an ampere-volt output which was only slightly above its normal rating. That is, the maximum that that generator could give was not double current or three times the normal current, but it was equivalent to only a little more than its normal output, so that it would hardly be reasonable to expect any motor to receive from that generator enough current to start the flour mill. The induction motor was first designed for better running than starting conditions, which was not the most favorable for that service. The men were required to pull on the belt. If I remember correctly I was one of the men at a certain time. He states that some four friction clutches were used in the mill. He did not state whether these were in series or multiple, but probably they were in multiple for different sections of the mill. May I ask how many friction clutches would have been required and what starting conditions would have been required, if a synchronous motor had been used in that case? He referred also to a 400 horsepower motor. If I remember correctly it was the same firm which had bought this first motor and put it in the flour mill, and had had these various troubles, which was later to equip another mill. Did they leave the induction motor and buy the synchronous motor, or take anything else? No. They used the same kind of a motor for that second place.

I am not quite sure what the reasons are here in Buffalo, but I learned just a few minutes ago, however, that after a large use of synchronous apparatus in one of the stations which we are to visit this afternoon, the latest addition there has not been a synchronous motor but a large induction motor.

Lastly, this is not so much a question of theory as a question of fact. What is the experience with the motors of the two classes? I have given this subject pretty careful attention for a number of years back, and have tried to put this question to plants operating synchronous motors and induction motors—"Where troubles have occurred, of whatever kind, would they have been prevented if the other kind of motor had been used?" There may be accidents which cannot be prevented. They may occur through carelessness; they may be caused by short-circuit on the line. It may be that a momentary short-circuit or accident on one line has caused the system to shut down and it has taken a little while to start up. Could the trouble have been avoided, could the system have been more easily started, or would the effects have been more disastrous, if the other kind of motor had been used?

SYNCHRONOUS MOTORS AND PHASE RELATIONS.

STEINMETZ, in an invaluable paper presented at the Nineteenth Annual Convention of the American Institute of Electrical Engineers, held at Great Barrington, Mass., June 18, 1902, upon "Notes on the Theory of the Synchronous Motor, with Special Reference to the Phenomenon of Surging," states that while an induction motor at constant impressed voltage is fully determined as regards current, power factor, efficiency, etc., by one independent variable, the load or output, in the synchronous motor independent variables exist, load and field excitation. That is, at constant impressed voltage the current, power factor, etc., of a synchronous motor may at the same power output be varied over a wide range by varying the field excitation, that is, the counter electromotive force or "nominal induced electromotive force." Hence the synchronous motor may be utilized to fulfill two independent functions, to carry a certain load and to produce a certain wattless current, lagging by under excitation, leading by over excitation. Synchronous motors are, therefore, to a considerable extent used to control the phase relation and thereby the voltage, in addition to producing mechanical power. The same applies to synchronous converters.

THE SIMPLIFICATION OF TELEPHONE EXCHANGES.

BY WILLIAM F. SMITH.

ABSOLUTE automaticity in the operation of a telephone system designed for use in large exchanges is not to be attained without a complexity of installation which will preclude commercial success, first, because of the great cost of plant, and second, because of interruption to service due to the inevitably frequent derangement of any one of the hundreds, if not thousands, of vital parts of the complicated mechanisms comprising its equipment. The system about to be described is semi-automatic rather than completely automatic in its nature. It still uses exchange operators, but their labors are lightened by automatic devices which improve the service so wonderfully that a single operator can easily handle practically double the number of subscribers which it is possible for an operator to manipulate by any other type of telephone exchange now in vogue. This gives warrant for the assertion that the system of the California Automatic Telephone Company, which is about to be described in its salient features, is abundantly possessed of every desirable feature of automaticity.

In this system a subscriber's set consists merely of a transmitter, a receiver and a magneto call bell, all neatly mounted as a compact unit on a wall plate, or, if desired, they may be set up as the familiar hand telephone. As the system is of the central energy type, local batteries are not installed at subscriber's sets. The subscriber is furnished with nothing else whatever, for all signals to central are sent in by circuits manipulated by the ordinary action of the subscriber in taking the receiver off the hook and replacing it thereon. A single local panel of an exchange consists, so far as outward appearances are concerned, of a subscriber's spring jack panel, an operator's plug, a ringing plug and the usual transmitter, receiver and circuit plugs Multiple, or trunking

SWITCHBOARD FOR UNITED STATES MINT BUILDING, SAN FRANCISCO, CAL.

ing panels, are merely duplicates of local panels with trunking spring jack panels added. Bearing these statements in mind, the reader may proceed to an understanding of the system itself.

Designating the two subscribers who would engage in conversation as the calling subscriber and the called subscriber respectively, the act of the calling subscriber in lifting his receiver off the hook causes a drop latch or shutter to be raised from directly over the panel hole of the calling subscriber's spring jack, and in so doing it exposes a white rectangular spot about one-eighth of an inch by one-half an inch in size, or a circle one-fourth of an inch in diameter, while on the face of the latch or shutter appears the number of the calling subscriber in white figures on a black background. Immediately the operator inserts plug and asks for the number wanted, and when this is obtained she withdraws the operator's plug and inserts the circuit plug in the jack of the calling subscriber, while the ringing plug is inserted in the jack of the called subscriber and left there. When the called subscriber lifts his receiver from the hook the ringing plug is automatically ejected from its spring jack and the operator closes in the two lines by inserting the remaining one of the circuit plugs. Finally, when the conversation is ended and the subscribers "hang up," the circuit plugs are automatically ejected and the lines are cleared for further business.

One feature of this system adopts the use of a ringing plug instead of a ringing key. The ringing plug has been adopted in preference to the ringing key for the reason that a busy operator cannot forget a call for a subscriber whose jack contains a ringing plug, although it is altogether too easy a matter for her to forget either the number or the ringing of a called subscriber when the ringing key is used. The presence of the ringing plug in the jack is ever a reminder that the called subscriber has not responded; when he does respond the ringing plug is automatically ejected and the switch is completed, and thanks to the automatic clearing mechanisms, the operator is not called upon in any way whatever to give further attention to the switch.

The proceedure thus far outlined relates to the use of the local panels, that is, for all instances wherein the spring jacks of both the calling and the called subscribers are located on the same panel. When they are located on different panels, as is almost universally the case, the incoming operator multiples or trunks over the call to the panel of the outgoing operator, as the operator on whose panel the number of the called subscriber may be termed. In this instance the incoming operator signals to the outgoing operator that a call is on a certain trunk line, at the same time giving the number of the called subscriber, and the outgoing operator rings up the called subscriber and completes the switch. Then, when the conversation is done, the hanging up of the receivers clears out all lines as before, without any effort on the part of either operator.

Here a very important feature of the system which is being described should be noted, and that is that before the call between any two subscribers can be completed, the operator must clear her talking instruments from the circuit by the withdrawal of the operator's plug, for obviously she cannot complete any switch which may be called for so long as her operator's plug occupies the spring jack of either subscriber. She can talk to either subscriber separately, but the rule will work both ways, for if she talks to one subscriber she cannot talk to the other at the same time, and *vice versa*, and neither can either subscriber overhear any conversation between the operator and the other subscriber. Absolute secrecy in conversation between subscribers is thus accomplished, and evesdropping on the part of "central," which the public so seriously objects to, is rendered impossible.

Again, another advantage of this system rests in the fact that when once a connection between two subscribers is made, neither the operator nor anyone else beside the subscribers themselves can interrupt the call or interfere with the conversation in any way, for the two lines over which the conversation is being carried on are tied together by mechanical means so that it is impossible for anyone other than the two subscribers themselves to break the connection and terminate the conversation. And this latter they do by the simple and natural act of hanging up their telephone receivers.

The beauty of this system can perhaps best be imagined by the ordinary business man, if a suppositious case be applied to a mercantile establishment where the stenographer or office boy is entrusted with the duty of handling the telephone switchboard. In this instance the mode of procedure is precisely as represented for a local panel. The boy receives the call, rings up the called 'phone, completes the switch and then goes off about other business. He cannot listen to what is being said, he cannot interrupt the conversation by pulling out the wrong plug in his inborn blundering way, and, in fact, he is of no further use for good or for ill in any way whatever so far as this particular switch is concerned. When they are through talking they hang up their receivers, the plugs fly out and clear the line, and everything is in readiness for a new call. Were it not for automatic clearance, the boy might be likely to forget to pull out the plugs, in which event either number might rattle the receiver hook until the crack of doom, but they would never get the operator however severely they might heap condemnations upon him. But all this is a too familiar story to the business man; it is as familiar as it is unnecessary, now that a system has been devised for its avoidance.

In ordinary telephone practice, such as that with which the public is most familiar, a subscriber's call is first indicated by the lighting of a miniature incandescent electric lamp, whereupon the operator, seeing that the lamp is lighted, inserts a circuit plug into the spring jack of the calling subscriber, and, after having thrown the lever of a listening key, asks for the number that is wanted. This obtained, she trunks the call through a multiple panel to the proper outgoing operator. Thereupon the outgoing operator indicates to the incoming operator that she is listening for the number wanted; the incoming operator gives the number, which is repeated back to her by the outgoing operator, and then the latter plugs the trunk line referred to in the spring jack of the called subscriber. Next she rings the bell of the called subscriber, and when he answers the conversation proceeds. If he does not answer, the outgoing operator has probably forgotten that she has only rung up once, and, also forgetting the length of time that has elapsed since she plugged in the switch, believes that the conversation has ended, and, noting nothing to the contrary, straightway pulls the plug and causes confusion, two operators and a subscriber or two become involved in a babelous imbroglio. But if, on the other hand, the switch has been made and the conversation has ended without hard feelings on the part of anyone, the hanging up of the receivers by the subscribers actuates a clearing out signal on the switchboard panels of each operator, whereupon they each pull out all plugs by hand. Of course they can and do listen to the conversation at any time, for listening keys are permanently provided for that purpose; in fact, the whole system is so arranged that "central" can either listen to or participate in any conversation whenever she pleases. Seriously, if the pubiic had any conception of the assumed-to-be-simple operation of making a subscriber's connection in any of the large exchanges of today, it would never complain at "central" for delays that might occur or for mistakes that she might make. The wonder is that the telephone girl of a busy exchange can keep her senses. If she were not called upon to "chip in" upon conversations, and if it were so that she would be relieved of the really arduous task of pulling out plugs of the subscribers and multiple panels, all as is easily accomplished by the system which this article describes, the existence of the telephone girl would be a less irritating, a less irksome and a less thankless one.

Nevertheless the troubles and annoyances occasioned to and caused by the telephone operator are inherent to the system commonly in use rather than to the operator herself. Each switchboard panel of a busy exchange is a perfect mesh of apparently intervoven circuit cords, to clear which, together with watching for clearing out signals, consumes by far the greater part of the

time and energy of the operator. Thus it is that a mistaken clearing signal or accidental loosening of a plug on either the multiple or the local panel will cause annoyance alike to the subscriber and the operator. Automatic clearance makes all this impossible, and, in doing so, relieves the operator to that extent that she can handle at least double the number of subscribers, as stated, which it is possible for her to take care of under any other system.

A representative installation of the character which this article describes is now nearing completion in the building of the United States Mint at San Francisco. It is purely a local system, in that the entire switching equipment is under the immediate control of a single operator, whose office outfit is shown in the accompanying half tone plate. The operators panel is a fifty-drop set, which is furnished with ten sets of circuit plugs, two ringing plugs and one operator's plug. Nothing else is contained therein, no listening keys and no switching-in keys being included for the reasons which have been set forth. Though the operator's panel is laid out for fifty stations, but thirty-five will be installed to begin with, and of these thirty-five stations twenty will consist of desk or portable hand 'phones and fifteen will be of wall sets of the type which is illustrated. The telephone equipment of the entire building will be operated by five cells of storage battery of small capacity on the operating circuit and three similar cells on the talking circuit. A small motor-magneto set furnishes alternating current for the operation of the ringing circuit. In addition, cross-talk is made impossible of occurrence because of the installation of a system whereby the talking circuit and operating circuit are cut out automatically. Moreover, the system uses condensers for the purpose, among others, of eliminating the buzzing and humming sounds which frequently prove annoying in the telephone.

In conclusion it may be stated that several commercial installations, other than the one referred to as under installation in the San Francisco Mint, have, by long and satisfactory periods of operation, demonstrated the thorough reliability of the system, which is as completely worked out for handling the business of the largest exchanges as it is for the work of a small local installation such as that described for the San Francisco Mint. It may be interesting to note that the system designed for use in large exchanges embodies a method whereby the subscriber is enabled to indicate to "central" by mechanical means and with absolute accuracy the number of the subscriber with whom he wishes to converse. This is done by the pushing of numbered buttons on the subscriber's telephone. In addition, each subscriber's telephone contains a printing attachment which enables the recording of calls that may be sent in during the absence of the subscriber. The value of these two improvements will be promptly recognized, especially when it is known that the automatic calling device referred to makes it no longer necessary for the operator to converse with a subscriber in any way, shape or manner. In accomplishing this there has been effected the last step which it is necessary to take to render telephony as automatic as it is reasonable and prudent to make it.

This summer has been a remarkable season for the elevator industry, the Otis Elevator Company reporting that within the past week they have closed contracts for no less than forty hydraulic passenger elevators to be installed in New York city in large office buildings.

Last week's orders included fifty-one electric elevators for New York city alone. Several of these are for the full automatic or push-button type, where no attendant is required. It appears that engineers and building contractors lean toward the modern Otis vertical cylinder hydraulic elevator for large office buildings and hotels.

That a bright future is in store for the electric automobile industry on the Pacific Coast is evidenced by the fact that a carload of these superb machines, consighed to A. E. Brooke Ridley, was entirely sold within ten days after its receipt in San Francisco.

THE LATE JOHN W. MACKAY.

I do not think there has been during the past decade a man whose death caused as great a shock, or such universal sorrow as that of Mr. John W. Mackay. It has been truly said of him that the world sustained an irreparable loss when he crossed the great divide. His sphere of action brought him into close relationship with rich and poor, strong and weak, and by all classes was he equally beloved and respected.

My acquaintance with Mr. Mackay dates from the old Bonanza days—from Virginia City in 1879—and since my first meeting with him I can truly say that the greatness of his character, the directness of his mind, the tenderness of his heart and absolute fearlessness made him a hero in my eyes in my younger manhood, and in later years commanded a respect and homage that is accorded to but few men.

Mr. Mackay was democratic to an unusual degree, receiving with the same friendly attention rich and poor alike, and according to all a quick and ready attention. His splendid judgment of human nature enabled him to discriminate between the worthy and unworthy—the sycophant and the friend—and he seldom, if ever, made an error as to the status of those surrounding him or those he came in contact with.

The colossal fortune he left behind him, and the magnificent achievement of the Postal Telegraph and Cable Company are sufficient evidences of his great business ability. Of his business character I know but little, except the great respect accorded him by all of his associates. It was my good fortune to have cognizance of many of his charitable acts. These have been exploited at some length in the daily and weekly papers by his more intimate friends, but the half has not been told, nor could the greatest research enable the world to know how great a help the throb of his kindly heart was to the unfortunate, the needy and helpless. Mr. Mackay had a faculty of forgetting his many kindly acts, and when evidence of indebtedness or letters of gratitude remained to remind him of them, he seemed uneasy until they were effaced.

Mr. Richard Dey speaks of his having destroyed promissory notes to the value of $1,200,000, constituting the only evidence of loans made by him to his friends. From this great fortune so generously lavished, his smaller donations and gifts of which the world never has known can be judged.

This constitutes but one side of Mr. Mackay's character, however. In business he was equally generous. It may not be generally known that out of his own private funds he presented on Christmas day to every employee of the Cable Company a check for one-half month's salary. Considering the number of these, the donation every Christmas must have amounted to a small fortune in itself. No employee of the Cable Company ever lacked for anything during a time of sickness and distress that Mr. Mackay could supply.

Such a man the world can never forget, and while he will occupy a niche in history as philanthropist, millionaire and upbuilder of enormous enterprises, his everlasting monument will be the magnificent example of benevolence, sturdiness, simplicity, self-reliance and generosity as exemplified in one of the greatest characters of the age—a character that will be held up to generations of rising young American manhood as a criterion to follow. It can be truly said that in the passing away of Mr. Mackay the world has lost A MAN.

J. M. SHAWHAN.

PROTECTION OF LONG DISTANCE TRANSMISSION LINES.*

BY DR. F. A. C. PERRINE.

IT is assumed that the subject of protection of long distance transmission lines is intended to cover only the question of protection of these lines against lightning and other static discharges, since any other interpretation of the word protection might involve every question concerned in the design and construction of such a transmission line. Essentially the protection of a long distance transmission line is the same as the protection of a shorter lower potential line, though by this I do not at all mean to convey the impression that the protection of high potential long distance lines is no more difficult than the protection of other lines, since, as all know who have attempted the problem, there are many new difficulties arising in this problem and many difficulties of inconsiderable amount in lower potential work which rise to great proportions in all long distance transmission work.

The reasons that there are greater difficulties in protecting long transmission lines are:

First, on account of the extent and character of the territory traversed. In the summer time lightning storms of small area are matters of frequent occurrence and the problem is sufficiently difficult where one has to encounter only the storms that occur in any one section of territory, but where lines extend over distances from twenty to fifty, or even up to 100 miles, it can readily be seen that the multiplication of the chances of interference from disturbances of atmospheric potential is very important, and that such a line must be protected efficiently at all times, irrespective of the particular character of the weather at the station, and, in consequence, those interesting means of lightning protection which are connected to the line only when danger is apprehended, cannot in such cases be contemplated. Furthermore, transmission lines pass through country varying materially in elevation, and in certain conditions of the atmosphere there are produced disturbances along the line entirely apart from the existence of any lightning storms.

All who have had experience extending over a number of years with alternating current line protection know that as the potential has been raised step by step new principles seem to become important in the construction of the so-called lightning arrester. The very means that might safely be used in protecting short low potential lines may cause damage in extremely long lines that would be worse than the difficulty they are desiring to eliminate. All apparatus producing open air arcs must be carefully avoided where the lines are long and the capacities and self-inductions great. Open air arcs being of rapidly oscillating character, actually raise the potential along such lines and introduce of themselves difficulties similar to those produced by lightning discharges.

Before going into any question of the actual means used for protection of long distance lines, we need first to recall to mind the fact that in protection of any line we are protecting, first against the induced surging currents on the line produced by neighboring lightning discharges; any lightning discharge in the neighborhood of a transmission line induces a high potential current on the line which must be safely gotten rid of. Secondly we must provide against the occasional striking of the line of a small side flash, and, finally, we must do what we can to protect against a direct lightning flash, though generally this is necessarily destructive where it hits.

General atmospheric differences of potential and small induced charges can be best taken care of by a frequently grounded wire run in the neighborhood of the line. The familiar barbed wire, stapled to the tops of the poles and grounded at least as frequently as every fourth pole, illustrates this perfectly. Some trouble has been met from this means of protection, but there is really no reason for any serious difficulty to be expected from this source. In the first place, it is necessary to buy a barbed wire made of first-class material, and not to apply to the nearest hardware store for the cheapest grade of fencing. For export and for this particular purpose a particularly high grade of barbed wire is made, which, if carefully stapled to the poles and not kinked where the staples are driven in, should give no trouble from falling and interfering with the transmission line. Wherever it has been used it is found at least to discharge the line when charged by differences of air potential and also to relieve the other means of lightning protection when a storm was encountered.

Choke coils, which are commonly used as a part of lightning arrester outfit, undoubtedly sometimes have beneficial effect if there is a separate path to earth through a set of arresters for every choke coil; but there seems to be no doubt but that their effect is present at certain rates of oscillation and not at others; consequently they cannot be considered as a sure means of aiding the lightning protection. The machinery itself generally has a very high self-induction, which tends to induce the charge to go through a neighboring set of arresters rather than through the machinery, and cables leading into the stations are likely to be a much more efficient means of preventing a charge from entering the machinery than protection offered by a choke coil. It is better to install choke coils and to obtain the slight additional advantage they give than to consider that without the use of choke coils there is necessity for only one path through the arresters to ground. It seems quite certain that any attempt to save lightning arresters by affording too few paths for the discharge to go to ground is the falsest sort of economy, and the only excuse for leaving out the choke coil in any lightning protection system would be the introduction of additional paths to ground scattered along the line, and not all bunched at the terminals, as is now the common practice.

If a high potential line is efficiently protected by the ordinary form of gap arrester, there sometimes is present on the line potential not sufficient to pass through the gaps of the arrester, and, at the same time, sufficient to pierce the insulation of the machinery. This high potential charge can be gotten rid of through small gap line dischargers, backed up by means for preventing the dynamo current from following the lightning discharge. One of the most efficient pieces of apparatus of this kind is in nature similar to the Branley coherer, which permits the passage of small currents of high periodicity and high voltage, but effectually prevents the passage of currents of low frequency and potential.

It hardly seems necessary in any particular way to call attention to the various standard lightning arrester types, since these are sufficiently familiar to all, but only to warn against the error of attempting to provide gap arresters with enough gaps for protecting high potential circuits and preventing the dynamo from following, since when the potential rises above about 30,000 volts, this type of arrester is no longer available and in series with a moderate number of gaps must be inserted either a resistance or a condenser, the probability being that the use of a condenser will be found to be the preferable plan.

Finally I would state that, with the use of a barbed wire, lightning arresters and line dischargers, we have done the best possible in the protection of any long distance lines, but, at the same time, feel constrained to confess that the engineers have still much to do before they can say that they have offered such perfect protection to long distance lines that there will be no further trouble from this source.

BY CHARLES H. BAKER.

The chief weakness in a transmission project is the transmission line itself. Although every precaution has been taken, and no expense spared in constructing well this artery between the generating point and the consumer, yet nearly all our troubles have centered here. Our line travels mostly through a densely timbered region, and we have consequently had to go to great expense in eliminating the dangers from falling trees and falling

*Abstracts of papers presented before the National Electric Light Association at Cincinnati, Ohio, on May 21, 1902.

branches by cutting through the forest a swath of varying widths, according to the height of the timber, in some places the belt cleared reaching 600 feet wide. The felling of the trees does not alone suffice, but they must be burned up and the debris cleared off in order to remove the danger of running fires in the dry summer weather.

We do not think a transmission system can be entirely reliable without a double circuit. Our present system transmits from the generating point at 30,000 volts by two circuits each to Seattle, and two circuits each to Tacoma. These circuits parallel each other for twenty miles, and at the twenty-mile point they are interchangeable through a high tension plug-board system. For this twenty miles we therefore have more assurance of continuity of service than from this point to the terminals, where only two circuits cover.

Built as our line is, and inspected as rigidly as it is, we have eliminated entirely all troubles due to falling trees, running fires or windstorms. In fact, our troubles narrow down entirely to those due to interference evidenced either by malicious persons or boys shooting off insulators or throwing wires over the transmission lines.

Our apparatus is protected by lightning arresters installed on the main circuits at the primary station and each of the substations. We have very little lightning in this country, and only once, I believe, in three years have these arresters actually been called to duty, and on this occasion they worked to perfection. All our circuits are fused at the different stations for 100 per cent. overload, so that in case of a dangerous short circuit coming in, the fuses open up and the apparatus is cut out.

BY L. DENIS.

The Quebec-Jacques-Cartier Electric Company has thus far had little experience with lightning trouble. Our transmission line consists of two three-phase 23,000 volt lines, some eighteen miles in length, and in several places passing in the neighborhood of tall trees. It is protected at both ends, at the very points where the wires enter buildings, with sets of Wurts lightning arresters, arranged in the standard Westinghouse fashion. These arresters are our only protection against lightning. Although they have been noticed to spark occasionally, we have never experienced more than the result of a partial short circuit from the discharge. We seem to have had more trouble from gradual discharges and from induced charges that take effect on the low tension side of our station transformers. We may add, for the sake of information, that this locality has quite a reputation for the severity of its lightning storms.

BY P. N. NUNN

We have at our several stations in Colorado, Utah and Montana, a number of lightning arrester installations. These installations are all of the Wurts type of non-arcing arrester, and consist of a number of paths to ground, with a number of choke coils between the line and apparatus to be protected. The exact arrangements employed are various and for voltages ranging from 4000 to 60,000 volts, the higher voltage being, in general, from star-connected transformers with neutral point grounded.

In all of these various installations an attempt has been made to improve upon the previous practice, and, in general, this has been successful. We have never had a serious disaster caused by lightning, or by the violent oscillations caused by the opening and closing of long power lines of large capacity and at a very high potential.

We have, however, had numerous small annoyances caused by lightning and the oscillations above referred to, and for this reason do not regard our present lightning protection as entirely satisfactory. For this reason we are now experimenting with the more recent type of arrester installation, including shunted and series resistances, and fewer paths to ground. This work has not passed beyond the first experimental stage, and we have no data to offer on it at present.

BY HENRY J. GILLE.

The St. Croix Power Company is operating a 25,000-volt transmission line, approximately thirty miles long, from Apple River Falls, Wis., to St. Paul, Minn.

At each end of the line is located a lightning arrester house. The lightning arrester house at the St. Paul end is within two miles of the substation and is also used as a cable terminal house. At each end of the line is a choke coil on each wire and twelve 2000-volt lightning arresters. Each arrester has four air gaps of about one-eighth inch each, cylinders being one inch by an inch and a quarter in series with two graphite resistances, each having a cold resistance approximately of 450 ohms.

From the cable terminal house the current is carried underground through cables at the line voltage to the substation. The cables are two in number, one insulated with rubber and the other with prepared paper, both being lead covered, and each of sufficient capacity to carry the entire load. In both cables there are three conductors, each conductor consisting of seven strands of copper wire.

At the substation in St. Paul there are cable terminals, switching devices and static arresters. The static arresters are lightning arresters, the same as described above, and are connected the same as lightning arresters, except that the center of the Y is not grounded. All feeders from the substation are underground.

During electrical storms the line is almost always affected in some way, sometimes very slightly and sometimes shutting the system down entirely. When the storm is severe we usually observe a discharge on one leg of the arresters. The discharge affects the generators at the power house practically the same as does a heavy short circuit, and there seems to be a strong tendency for part of the generators to motorize and always slow down. In some cases they have come practically to a standstill. We have had several cases where the lightning has apparently disregarded the choke coils and the lightning arresters and damaged the static transformers.

At the substation the synchronous converters slow down, but apparently remain in step until the fields become practically dead. This occurs in about ten seconds. When the generators begin to pick up again at the power house the rotaries also come up with considerable flashing at the brushes. Sometimes they come up with the polarity on part of the rotaries reversed. If they all come up right side up they pick up the load and carry it along as if nothing had happened, but if part of them came up wrong side up it is necessary to shut down and change the polarity.

The alternating current system is not so easily affected as is the direct current system. When the transmission line is affected by lightning discharge and the current comes back in the substation, the circuit breakers on the alternating current feeders usually open up, especially on feeders where there are induction motors. This is without doubt due to the fact that the induction motors will take considerably more current to bring them to speed again than is required when they are up to speed, that being practically the only time when all the induction motors on the circuit are started at the same time, these circuit breakers, therefore, open up, due to a heavy overload.

There is evidence on a great many poles on the transmission line of discharges jumping from the wire to the poles. We have not had poles so badly damaged that they have had to be replaced, but some of them were badly split. At the time of these discharges the insulators on the line were apparently not affected; as a matter of fact, we have had no insulators broken through lightning discharge.

The lightning arresters and static arresters are so adjusted that they discharge constantly, the discharge being very light, being visible only on two or three air gaps next to the line wire. The lightning arresters at one end of the line were very badly damaged during one storm last summer, when the discharge apparently jumped from the line to the ground, arcing across the cylinders without regard to the resistances, forming a straight path to the ground. How long this arc was held we do not know;

however, it held long enough to do considerable damage to the cylinders and porcelain.

BY P. M. LINCOLN.

The effects of lightning on the Niagara Falls-Buffalo transmission line may, for the purpose of discussion, be divided into two classes: (1) Those lightning discharges which cause destruction of apparatus attached to the transmission line; and (2) those discharges which cause a general short circuit, but without the destruction of any apparatus.

So far as destruction of apparatus is concerned, the Niagara-Buffalo line has been peculiarly fortunate. During the five and one-half years of its operation practically the only apparatus that has ever been destroyed by lightning has been lightning arresters.

In the matter of lightning arresters, however, the line has not been so fortunate. Several different styles and makes have been installed and tried, with the result of ultimate disaster to the arrester. Failure has been due to the inability of the arrester to interrupt properly the dynamo current that follows the discharge, and the resulting short circuit at the arrester would usually put it out of business, at least temporarily, and occasionally permanently. The conditions at Niagara are, of course, unusually severe. The low frequency and the large amount of power involved make it difficult to interrupt a short circuit when once started. Devices that work perfectly on higher frequencies and with less power back of them have failed utterly on the Niagara-Buffalo line. One of the things which I consider that the experience of this line have proven is that it is absolutely necessary to limit, by means of resistance, the dynamo current which flows on the discharge of the arrester. No matter what the number of gaps through which the discharge takes place, an arc once started seems to be maintained unless the dynamo current is thus limited.

The device that comes nearest answering our lightning arrester problem is the one now in operation; that is, the so-called "low equivalent" lightning arrester manufactured and installed by the Westinghouse Electric and Manufacturing Company. In that device the gaps have an ohmic resistance in series with them and another larger resistance in shunt to a portion of the gaps. This arrangement gives the line discharging effect of the small series resistance and the current interrupting effect of the combined series and shunt resistances. In their original form these were put into operation in the summer of 1899, and are still in use in a somewhat modified form. Our former experience, however, has led to the adoption of fuses in the discharge circuit, so that in the case of a short circuit taking place in the arresters, both line and arresters are protected, the line from a continuation of the short circuit and the arresters from the damage that would necessarily follow that continuation. In all our lightning arresters choke coils are put in the lines and the discharge circuits tapped on the line side of the choke coils.

Our observations would indicate that the voltage necessary to jump over a wet insulator does not differ greatly from that required to jump across the gaps of the lightning arrester. In case such a short circuit is once established anywhere along the line, it almost always continues until the current is pulled off the lines, in spite of the fact that the distances between our conductors is thirty-six inches. Most of our lightning interruptions are of this nature. No permanent injury is done. All that is necessary is to take off the current for an instant; supply of power can be resumed immediately.

DISCUSSION.

Charles F. Scott, Pittsburg, Pa.—One of the functions of the lightning arrester, its ability for protecting circuits and other apparatus, has been fairly satisfactory, but going up to these very high voltages, as Dr. Perrine has pointed out, brings in new conditions which it is impossible for the designers to meet without getting the practical conditions of the operating circuits. That is a matter which Mr. Wurts gave some attention to a few years ago, and Mr. Thomas of the Westinghouse Company, who has recently presented a paper before the American Institute of Electrical Engineers, expects to go out and visit some of these plants this summer and make investigations on the ground. It is a most excellent thing to bring up a subject of this kind before the practical men in the business in order that they may keep in touch with the designers of lightning arresters and help them in making apparatus which will meet the practical conditions. The fact that these lines have been operating, and operating well, going into these very high voltages, within the last few years, seems to me to speak well for what we may hope to have in the course of a few years, as the conditions are better known and the apparatus can still be further perfected. The arrangement which Mr. Lincoln spoke of, namely, a combination of series and shunt resistance, is one which was the result of a considerable amount of experimental work at Niagara Falls, on the machines which are installed there, to determine the proper proportions for interrupting discharges (artificial in that case) across the arrester gap, and that which Mr. Lincoln has pointed out as being the most satisfactory arrangement on his circuits is the one which Mr. Nunn and Mr. Thomas are trying in conjunction on the high voltage circuit which Mr. Nunn has out on his lines. Mr. Nunn can be considered as one of the pioneers of this high voltage work, having operated a 40,000-volt line, I believe a considerable time in advance of others, and his testimony on this subject is very excellent and valuable.

Dr. F. A. C. Perrine, Pittsfield, Mass.—I suggest to Mr. Lincoln if he finds that the barbed wire will not stand up under the strain of sleetstorms, that he have it made of plow steel, and it will stand as well as copper. The barbs are undoubtedly effective in protecting the line.

THE CURRENT REQUIRED BY ELECTRIC MOTORS.

A RECENT number of *Science and Industry**, a superlative little engineering magazine published at Scranton, Pa., contains as a supplement a table showing the current taken, at full load, by various sizes of electric motors of both direct and alternating current types, at the ordinary pressures of 110, 220 and 500 volts.

The ampere consumption of direct current motors depends directly upon the efficiency of the motor, and with alternating current motors it depends upon both the efficiency and the power factor of the motor. These qualities vary somewhat in motors of different make, so the values given in the table herewith may be considered as fair, rather than exact, averages. They are useful in making wireing calculations, fusing, etc. The current given for two-phase motors is the full load current of each phase; the current for the three-phase motors is the current in each of the three wires leading to the motor.

H. P.	Direct Current Motors			Alternating Current Motors.								
				Single-Phase			Two-Phase (4 Wire)			Three-Phase (3 Wire)		
	110 v.	220 v.	500 v.	110 v.	220 v.	500 v.	110 v.	220 v.	500 v.	110 v.	220 v.	500v.
1	9	4.5	2.0	14	7	3.1	6.4	3.2	1.4	7.4	3.7	1.6
2	17	8.5	3.7	24	12	5.3	11	5.7	2.5	13	6.6	2.9
3	26	13	5.6	34	17	7.5	16	8.1	3.5	19	9.3	4.1
5	40	20	8.8	52	26	11	26	13	5.5	30	15	6.4
7½	60	30	13	74	37	16	38	19	8.1	44	22	9.3
10	76	38	17	94	47	21	44	22	10	50	25	12
15	112	56	25				66	33	15	76	38	17
20	150	75	33				88	44	19	102	51	22
30	226	113	50				134	67	29	154	77	33
40	302	151	66				178	89	39	204	107	45
50	368	184	81				204	102	45	236	118	52
75	552	276	122				308	154	68	356	178	77
100	736	368	162				408	204	90	472	236	104
150	1110	555	244				616	308	135	710	355	156
200	1474	737	324				818	409	180	940	470	208

**Science and Industry*, Volume VII, August, 1902.

The Otis Elevator Company has received an order from the General Electric Company for seven complete electric elevators with Otis motors and controllers for installation in the shops at Schenectady.

PERSONAL.

B. C. VAN EMON has been identified with the electric power interests of San Francisco since their earliest inception, for his career in that direction begins at the time when Adolph Weschke started the first electric power circuit in San Francisco in 1886. He remained with Mr. Weschke for about a year, or until the time when Dr. N. S. Keith began to deliver electric power from the plant which he installed on the second floor of the building of the San Francisco Tool Company. Those were the days when shunt wound constant current dynamos were used, and electric motors were similarly of the constant current type, but equipped with heroic expedients for controlling speeds. The machines were not supposed to last long, either, and young Van Emon found no lack of work in his position of armature winder and builder and repairer of dynamos, motors and arc lamps for the tool company. This old plant was the forerunner of the Pacific Power Company, which has recently passed into the control of the Standard Electric Distribution Company, and as such will form the entre of the Standard Electric Company's transmission into San Francisco.

B. C. VAN EMON.

It was in the latter part of the eighties when the late George H. Roe and Dr. Keith founded the Electrical Engineering Company for the purpose of building, more especially, dynamo electric machinery. The location of the engineering company at the time of its commencement was 23 Spear Street, and as soon as it was established its shop was placed in charge of Mr. Van Emon as foreman, which position he held for five years when the works were moved to 34 Main Street, soon after which he was promoted to the position of general superintendent of the establishment. In 1896 Mr. Van Emon was made manager of the company, which position he held until June 1st last, when he resigned. He has since established the Van Emon Engineering Company, of 137-151 First Street, San Francisco, as reference to the advertising columns of THE JOURNAL shows.

Much of the early development of electric power in elevator, hoisting and even transmission work in California was done through the energy and progressiveness of the Electrical Engineering Company, in which, as has been intimated, Mr. Van Emon was the leading engineering spirit. He is the patentee of all the elevator and motor controlling devices which ever appeared in the engineering company's equipments, and when it is remembered that the company has over 300 direct current electric elevators of its own manufacture and installation in operation in San Francisco alone, an idea of the responsibility of his position and the satisfaction which has attended the execution of his work may be gathered.

Mr. Van Emon's electrical experience contains much that is of interest along the line of early transmission history. All his early work in this direction was with constant current apparatus, which, though now obsolete in power transmission, did much toward demonstrating its practicability. In 1891, for instance, the engineering company installed a 100 horsepower, twenty ampere constant current power plant in the Black Diamond coal mines at Carbonado, Wash., for pumping (twenty-five horsepower) and hoisting (fifty horsepower) duty. This plant ran for six years before being superseded. In 1892 the engineering company installed a 100 horsepower, 1000 volt, direct current, two and one-half mile transmission in Grub Gulch, Madera County, Cal., for the operation of the ten-stamp mill, the twenty horsepower hoist and the two ten horsepower pumps of the Mammoth Gold Mining Company. This plant ran for nearly five years. In 1895 it installed a 150 horsepower, one and one-half mile, 1000 volt transmission in Gold Valley, Sierra County, Cal., for the Gold Valley Mining Company, the power being used in driving a twenty stamp mill and a sixty horsepower air compressor. The plant ran for about four years, when the mine shut down. In 1895 there was installed a fifty horsepower, one and three-quarter mile, 1000 volt transmission for the operation of a fifteen horsepower hoist and ten horsepower in pumping at the mine of the Occidental Gold Mining Company, Iowa Hill, Placer County, Cal. In the same year (1895) a duplicate of the Gold Valley equipment was installed for the Mammoth Bar Gold Mining Company, of Placer County, with the exception that in the Mammoth plant two twenty-five horsepower and one fifty horsepower motors were used to drive centrifugal pumps. In 1898 there was installed at the Montauk (Zantgraf) Mine in El Dorado County, Cal., two 500 volt constant potential direct current dynamos of 125 horsepower and seventy horsepower respectively, each being separately belt-driven from a water wheel. The distance of transmission is 2700 feet, and the load consists of thirty horsepower on the stamp mill, fifty horsepower on the hoist and ten horsepower each on the rock breaker and two pumps. This installation marks the breaking away of the Electrical Engineering Company from constant current to constant potential types, and as such closes this brief review of Mr. Van Emon's contribution to the early transmission development. It is interesting to note, however, that he has recently installed two twenty horsepower two-phase induction motor elevator equipment in the *Deseret News* building at Salt Lake City, and that their operation has been such an unqualified success that the order has been duplicated for the passenger elevator equipment of a new building which the same owners are erecting.

MR. FRANK H. TAYLOR, recently appointed second vice-president of the Westinghouse Electric and Manufacturing Company, has thus risen to a position which makes him an even more important factor in the electrical business of the country than he has hitherto been, although his previous position with the Westinghouse company as fourth vice-president, in charge of sales, has made him well known throughout the electrical business.

Mr. Taylor is a native of Cincinnati, where he was born November 20, 1855. He graduated from Haverford College, near Philadelphia, with the degree of A. B., going thence to Harvard University, where he also took the degree of A. B., graduating in 1877. While at Harvard he was captain of the cricket team, and it may be remarked in passing that he is still an enthusiastic and active cricketer, being the moving spirit in the sport in the Pittsburg district. It is interesting in this connection to note that his eldest son is at the present time captain of the cricket team at Harvard. After leaving college he learned the trade of starch maker, and was for a short time a professional starch maker, and from 1880 to 1882 was superintendent of the George Fox Starch Manufacturing Company, Lockland, Ohio. In 1882 he removed to Philadelphia, where he assisted in the organization of the Manly-Cooper Manufacturing Company, afterwards known as the Belmont Iron Company, whose product was ornamental and structural iron and steel. He was treasurer of this company until 1887, and was then elected president. The works were destroyed by fire in 1888 and not rebuilt.

FRANK H. TAYLOR.

From January, 1890, until October, 1897, Mr. Taylor was the manager of the Philadelphia house of the Yale & Towne Manufacturing Company, handling their business in cranes as well as in hardware. His fine record as manager of this office attracted the attention of the officials of the Westinghouse Electric and Manufacturing Company, who in 1897 induced him to enter the

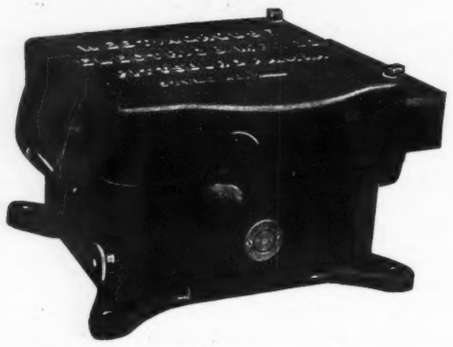
service of the company as sales manager, which gave him a larger opportunity for the display of his ability. The record he made was so good that in October, 1900, he was elected fourth vice-president of the company, charged with the sale of the company's product. In January, 1902, upon the resignation of his old friend, B. H. Warren, with whom he had previously been associated in the Yale & Towne Company, as well as in the Westinghouse company, he was made second vice-president of the latter, thereby becoming, next to Mr. Westinghouse himself, the executive head of this great company's affairs.

Mr. Taylor is a man of attractive personality, great energy and remarkable quickness in grasping the salient features of a proposition. He is happily married, and has four sons, who give every indication of being as keen in their pursuit of athletics as he is.

AUTOMATIC CAR TYPE CIRCUIT BREAKERS.

THE protection of railway motor equipments by the use of a fuse has until recently been the standard practice and recommendation of electrical manufacturing companies. The results obtained have been satisfactory only to a limited degree, as the fuse frequently fails to blow at the proper time or to give the equipment the best protection under all conditions of service. The necessity of carrying extra fuses, as well as the inconvenience of stopping the car to replace a blown out fuse is more or less of an objection to this method, and many of the largest street railway companies have replaced the fuse block with the automatic car circuit breaker. This practice offers better protection to the equipment, as it reduces to a minimum the possibility of injury to the apparatus arising from the carelessness of the motorman in improperly cutting out resistance—the circuit breaker will open automatically when the current reaches the value for which it is set.

Aside from the protective feature of a circuit breaker, the convenience in resetting it is obviously of great value. The motorman in throwing the handle of the breaker after the occurrence of a heavy overload or short circuit is not required to leave his position at the controller to put the car in service. In most cases it is not necessary to stop the car, as the breaker can be reset while drifting.



WESTINGHOUSE CAR TYPE CIRCUIT BREAKER.

The automatic car circuit breaker manufactured by the Westinghouse Electric and Manufacturing Company performs the function of the fuse block by opening an overload or short circuit; it also replaces the platform or canopy switch, in that it provides a hand opening for the circuit. In construction the instrument is thoroughly fireproof, of the best material and workmanship throughout, and all parts are interchangeable. Its design prevents arcing at the current carrying contacts, as the arc is broken on extra contacts especially provided for the purpose and assisted by a powerful magnetic blow-out which will open the severest short circuit without damage. The breaker is calibrated, enabling it to be set to open at any current within the limit of its range, and the automatic opening device insures absolute certainty in opening when the current reaches the predetermined value.

TRANSMISSION IN STREET RAILWAY WORK.

OF constantly increasing importance is the line of electrical engineering work which makes application of electrically transmitted power for the operation of street and interurban electric railway systems. The present status of this branch of electrical development is such as to represent capitalization of almost hundreds of millions of dollars, and while hardly more than the imitation of transmisson railway systems are to be found on the Pacific Slope, the densely populated districts of the East are becoming closely interwoven with them. The journals devoted especially to electric railway interests are teeming with descriptions of them, and it is not an overestimate to assert that so far as the East is concerned electric power transmission is finding its most noteworthy usefulness in its application to street railway work.

An article of this nature, which is characteristic of these publications, appears in a current issue of a Chicago periodical,* and is descriptive of the Aurora, Elgin and Chicago Railway system, which embraces electric railway lines permeating the principal communities of Du Page, Kane and Kendall counties, lying to the west of Chicago. The lineal distance covered is practically thirty-four miles, to which is tributary a population of over 107,000 people outside of Chicago. It is a third-rail line, laid throughout with eighty-pound T-rails, in sixty-foot lengths, and is bridged and ballasted according to the best steam railway practice, so as to enable the operation of trains at high speed. Power for the operation is derived from steam plants, the main generating station being at Batavia, which is designed for four main generating units, each comprising a horizontal cross-compound engine of the Corliss type, direct connected to a 1500-kilowatt, General Electric, three-phase, twenty-five cycle, 2300-volt generators, running at seventy-five revolutions per minute. Two of these units are at present in operation and the third is in process of erection. There are six substations in the system, these being operated from the nominally 30,000-volt transmission lines. The high potential lines are carried on forty-foot poles, with seven-inch tops, which are placed eighty feet apart. The crossarms are four and one-half by five and one-half inches in section, spaced twenty-four inches between centers vertically, the upper arm designed to carry two insulators, sixty inches between centers, and the lower arm to carry four insulators, sixty inches between centers, thus providing for duplicating the present feeder system when the demand for it shall arise. The insulators are the Locke No. 117, side and top groove triple petticoat, seven inches in diameter and four and one-half inches high, of glass, made by Fred M. Locke, Victor, N. Y.; these are designed for a working pressure of 30,000 volts. The high tension wires are transposed every mile.

Telephone wires are carried on crossarms about seven feet lower on the poles; these wires are transposed at every fourth pole. There are two complete telephone circuits, one intended for the train dispatcher and one for the general business of the company; but the dispatcher may interchange the systems. Telephone booths are placed at all switches and crossovers, and, of course, in the substations. At intervals of about 1000 feet wires are brought down the poles for connecting to telephones carried in the cars.

The six substations are located so that they form convenient centers of distribution. The continuous current produced at the substations is fed directly into the third rails, so that all direct current feeders are done away with. Outside of the substations the only cables used are for connecting the ends of the third rail at streets and grade crossings with other railroads. The electrical equipment of all the substations is practically identical and consists mainly of General Electric air blast transformers, wound for a primary voltage of 26,400 and a secondary voltage of 430, and General Electric rotaries, type H. C., running at 1500 revolutions per minute, and delivering direct current to the rails, as stated, at 600 volts. Each motor car is equipped with four General Electric sixty-six inch motors of a capacity of 125 horsepower each, making a total of 500 horsepower per car.

Street Railway Review, Volume XII, page 441, *et seq*, August 20, 1902.

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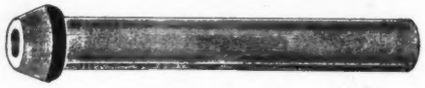

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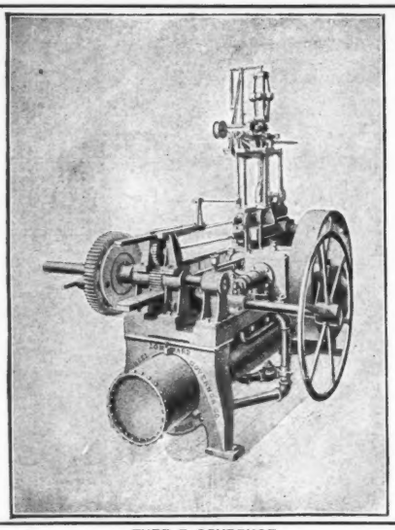

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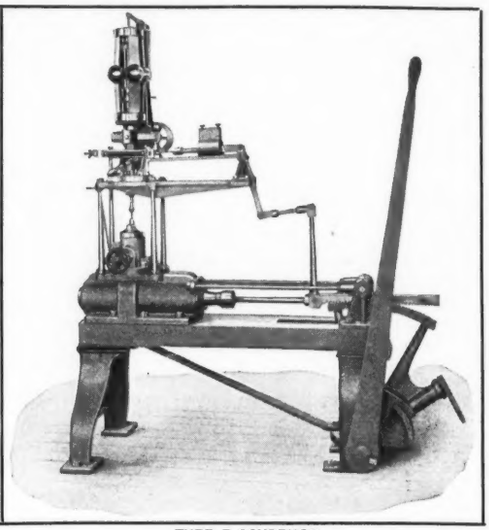

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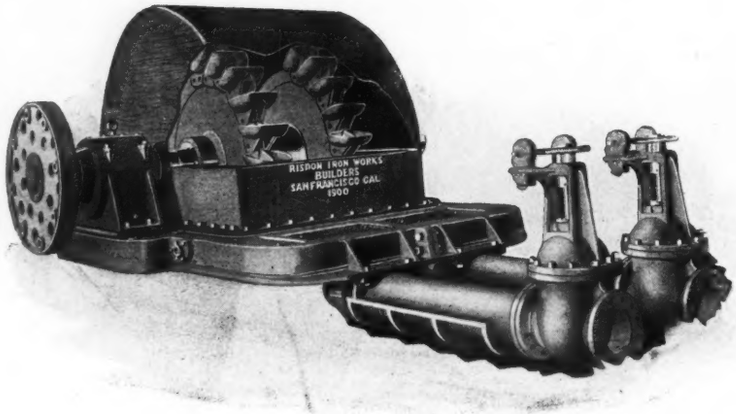

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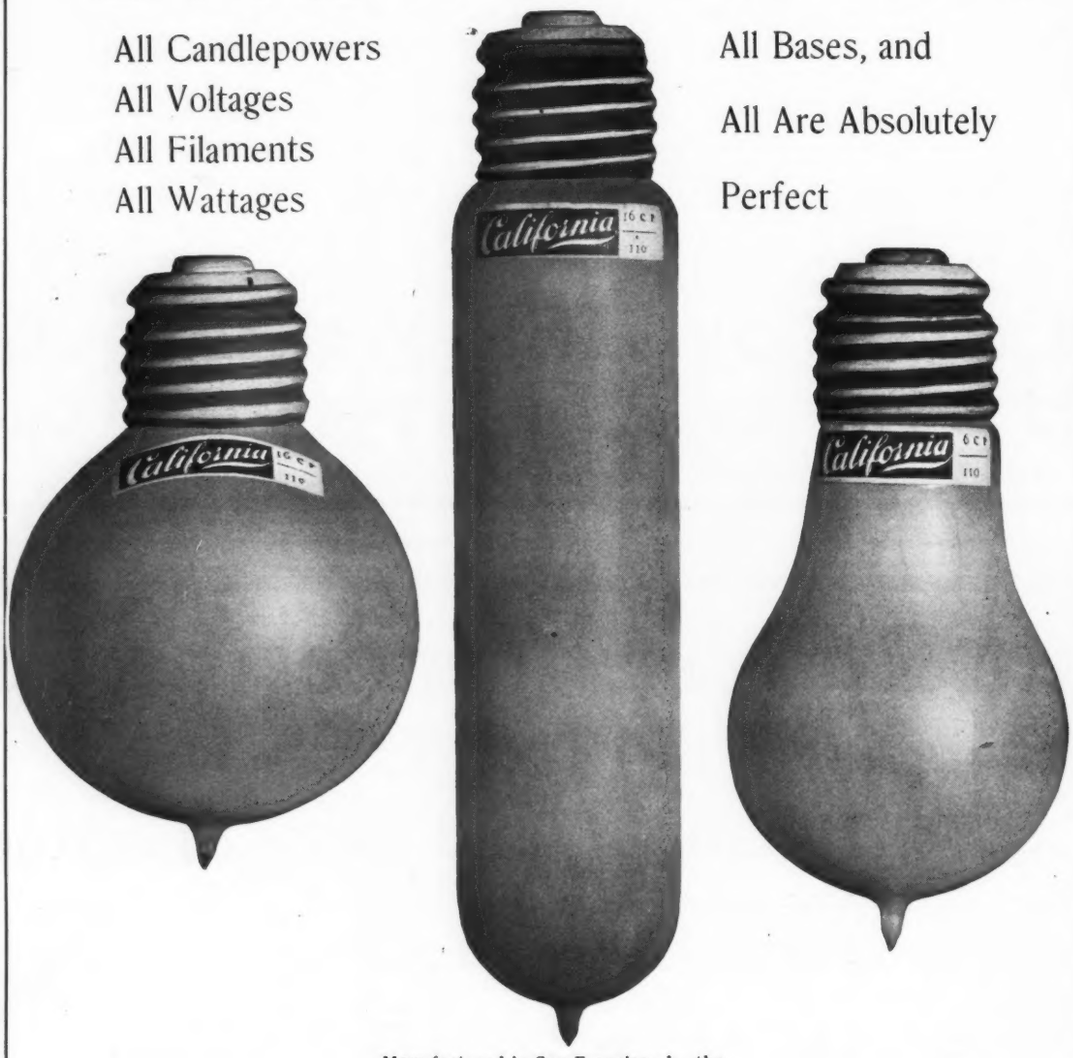

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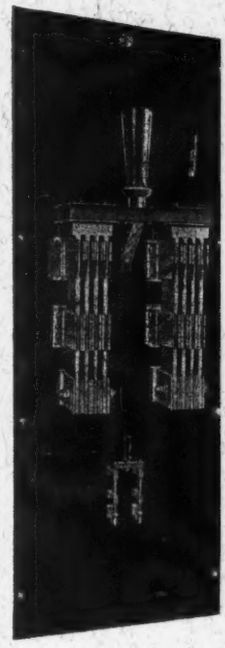

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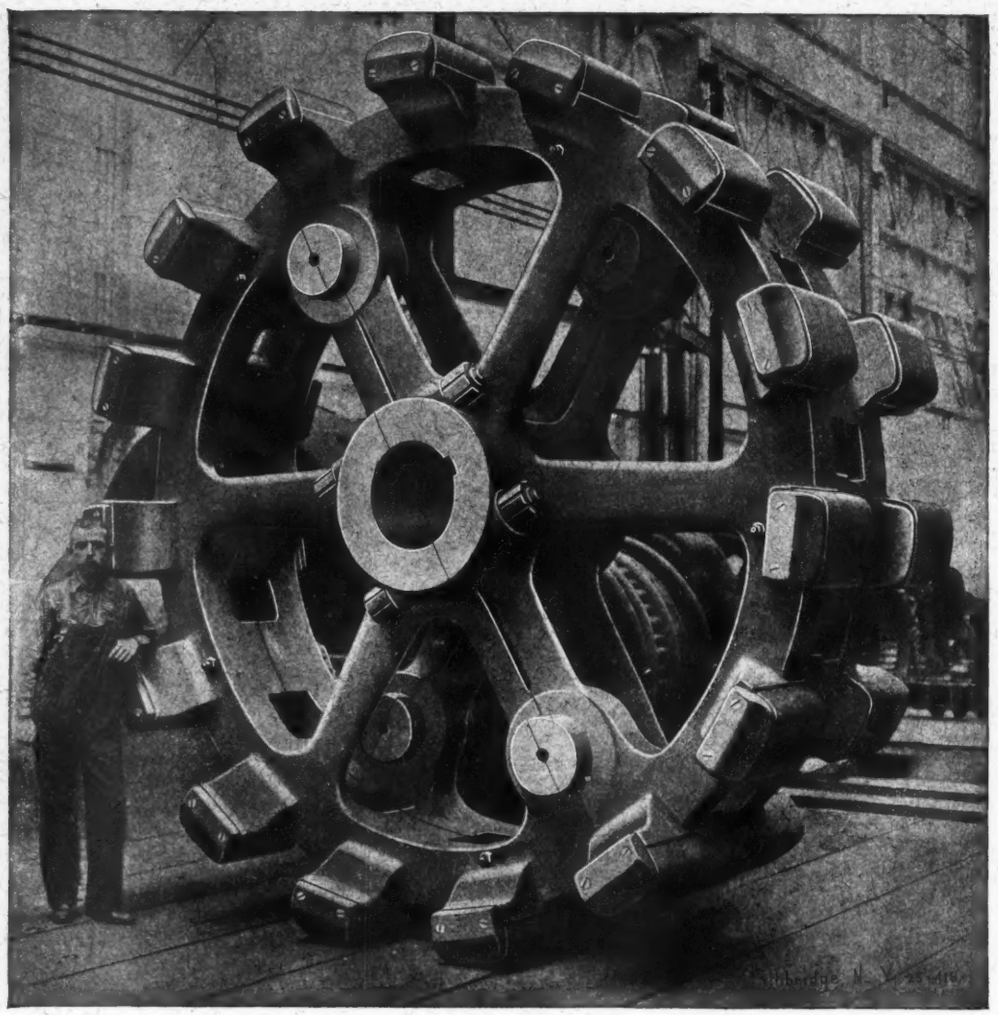

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